REPORT 4 FROM A REAPPRAISAL OF THE FOREST SITUATION

WOOD WASTE IN THE UNITED STATES

U. S. Department of Agriculture - Forest Service

1947

The following Reappraisal Reports have already been issued by the United States Forest Service:

No. 1. Gaging the Timber Resource of the United States

No. 2. Potential Requirements for Timber Products in the United States

No. 3. The Management Status of Forest Lands in the United States

No. 4. Wood Waste in the United States

No. 5. Protection against Forest Insects and Diseases in the United States

FOREWORD

During 1945 and 1946 the Forest Service made a reappraisal of the Nation's forest situation. This undertaking, carried out under the general direction of R. E. Marsh, brings up to date previous analyses of a similar nature.

This report covers one phase of the reappraisal. Other reports deal with different aspects, and with the situation as a whole.

It is a matter of general knowledge that an enormous amount of wood is wasted every year in converting trees into usable products. Past surveys of wood waste have been localized or specialized. This is the first attempt by the Forest Service to size it up on a Nationwide basis. The report analyzes waste in unusual detail, recognizing not only regional and industry variations, but also differences in the kind and amount of waste as these are related to logging and manufacture. It deals with waste from chemical processes using wood as a raw material as well as with wood waste as such. With this information the separate causes of waste can be more carefully weighed and the possibilities for better utilization more adequately considered.

In this study available data on waste were supplemented as necessary by field checks or by complete field studies. Most of the basic information on logging and manufacturing waste was supplied by the regional offices and experiment stations of the Forest Service. The Forest Products Laboratory contributed very substantially, especially information on chemical waste and possible methods of reducing all categories of wood waste.

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Chief, Forest Service

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WOOD WASTE IN THE UNITED STATES

INTRODUCTORY SUMMARY: THE NEGLECTED FOREST

To supply our various needs, we drained 12.2 billion cubic feet or 188.5 million tons of wood from our forests in 1944. This is an enormous quantity, much more than our forests in their present condition can continue indefinitely to supply in desired sizes and qualities. But it was not enough for us in 1944, and, barring depression, will not be enough for us in the future. Yet in these present years of scarcity, only 43 percent by weight of the wood we cut or destroy in logging or import appears in products other than fuel. Thirty-five percent is not used at all; the remaining 22 percent is used as fuel--much of it inefficiently. With a commodity[1] drain of 12.2 billion cubic feet and a small volume of imported wood, we wasted altogether or burned for fuel 6.5 billion cubic feet; and this does not take into account the lignin, cellulose fibers, and other chemical components lost in making pulp and paper. As table 1 shows, the waste[2] totals 108.9 million tons. Figure 1 shows how much of the wood survives logging and manufacture.

Logging waste amounts to 49 million tons (3.1 billion cubic feet), 45 percent of our total waste. Only 7 percent of it is used for fuel.

Primary manufacturing of wood into products like lumber, wood pulp and paper, veneer, ties, etc., wasted 52.9 million tons of wood, or 49 percent of the total. Of this 1.6 billion cubic feet was in slabs, edging, and other coarse waste; 1.3 billion cubic feet in sawdust and other fine material; and in addition 8.6 million tons was in chemical wastes from pulping. More than 60 percent of the primary manufacturing waste was burned for fuel.

Secondary manufacture wasted 7 million tons (0.5 billion cubic feet) of wood in 1944. Practically all of this was burned for fuel.

None of these figures includes waste of bark, conservatively estimated at 1.8 billion cubic feet. A little bark of some species is used for tannin, medicines, roofing, insulating material, and certain specialties. Much is burned as fuel along with slabs and edgings. At pulp mills it is generally used as a fuel, although often inefficiently, because the water it absorbs during barking is incompletely removed.

1/ In addition to the drain for commodities, there is a noncommodity drain caused by fire, insects and diseases, wind, etc. The average annual noncommodity drain for the 10-year period 1934-43 was approximately 1.5 billion cubic feet.

2/ As used in this report the term waste includes material not used at all and that burned for fuel. It does not include the fuel from trees cut for that use.

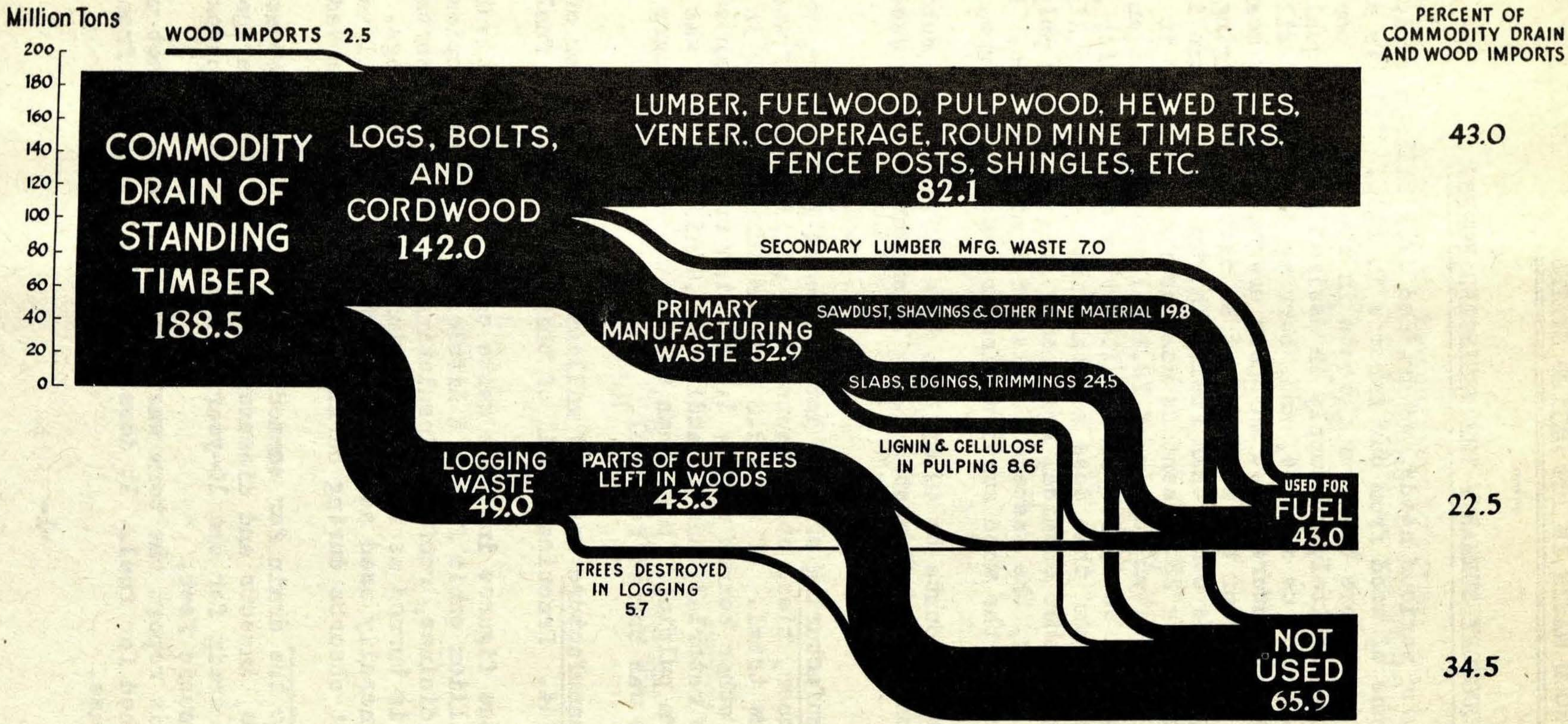

FIGURE 1.- USE AND WASTE IN LOGGING AND MANUFACTURE OF ALL TIMBER PRODUCTS, UNITED STATES, 1944.

Table 1.--Wood waste in the United States, 1944

Source of waste	Used as fuel		Not used at all		Total		Percent 1/
	Million tons 2/	Billion cu. ft.	Million tons 2/	Billion cu. ft.	Million tons 2/	Billion cu. ft.	
Logging	3.3	0.2	45.7	2.9	49.0	3.1	45
Primary manufacture: 3/							
Coarse material	15.3	1.0	9.2	.6	24.5	1.6	23
Sawdust and fine material	12.2	.8	7.6	.5	19.8	1.3	18
Lignin and cellulose in pulping	5.2	(4/)	3.4	(4/)	8.6	(4/)	8
Secondary manufacture of lumber	7.0	.5	..	..	7.0	.5	6
Total	43.0	2.5	65.9	4.0	108.9	6.5	100
	Percent		Percent				
Summary	40		60				

1/ Weight basis.

2/ 2,000 pounds on an oven-dry basis.

3/ Includes waste from imported wood.

4/ Tons of lignin and cellulose lost in pulping not converted into cubic feet.

For some products, of course, logging and primary manufacturing losses are greater than for others. Waste in making fuel wood, fence posts, and round mine timbers is low. By contrast, however, 72 percent of the cubic volume of a tree cut for cooperage is lost; for hewed crossties, 70 percent; for lumber, 68 percent; for veneer, 66 percent.

At least two considerations prevent us from taking much comfort from the fact that 40 percent of our logging and primary manufacturing waste is burned for fuel. Many sawmills and wood-using plants burn their waste as boiler fuel, but oftentimes a great deal more wood is consumed than is required for efficient heat. Much of it is burned green in fireboxes not designed for maximum efficiency. Secondly, much of the waste used for fuel can be put to such higher uses as pulpwood and small-dimension stock, if economical handling and processing techniques can be developed.

Our 6.5 billion cubic feet of waste wood plus 8.6 million tons of lignin and chemical waste are no mere statistics. They constitute a national problem. Some part of this waste can be converted to

products needed to satisfy human wants. Waste from sawmills, for example, can be made into cut-up stock or converted to alcohol, plastics, and a host of other items. In the main, however, these items are not direct substitutes for such items as lumber, railroad crossties, veneer, and cooperage stock, and their use would not appreciably diminish the drain on the growing forest. We cannot, therefore, expect to wring enough from our waste to eliminate our shortages or obviate the need for comprehensive forest conservation action. Nevertheless, whatever wood we can save that is now wasted, or can economically use for a higher purpose than it is now put to, will advance the Nation's welfare by providing useful goods, additional industry, and employment.

It is no exaggeration to call the waste a neglected forest. Certainly there is enough of it to justify the name. Often, too, it is there for the taking. Unfortunately, however, much of the waste wood is so scattered that it cannot be economically salvaged. Several lines of action hold promise of reducing waste or of utilizing more of it: (1) Greater integration of the timber products industries, (2) extension of sustained-yield forest management, (3) research to find ways of making old products with less waste or to devise new ways of using material now wasted, (4) technical assistance to woodland owners and wood processors, and (5) public aid in pioneering operations to establish the practicability of new waste-reducing or waste-consuming processes.

THE NATURE, QUANTITY, AND LOCATION OF THE WASTE

Throughout this report the term waste wood means wood material from the forest which does not appear finally in marketable products other than fuel wood, regardless of whether it is economically or technologically feasible to utilize it. As used here, waste does not include byproducts like lath, shingles, pulpwood, wood flour, and baled shavings, nor does it include the volume of trees cut primarily for fuel wood. It does include byproduct fuel wood from trees cut chiefly for some other products and, of course, wood not used at all, as well as unused wood cellulose fibers, hemicelluloses, lignin, tannin, sugars, gum, and other substances lost in processing.

Concepts of waste naturally differ widely. A sawmill operator might regard as waste all wood that does not appear in boards. Where lumber and paper manufacture are integrated, only material not appearing as either lumber or paper is wasted. If to these industries is added a hardwood distillation plant, waste is still less. Thus, the greater the degree of integration of the wood-using industries the less the waste.

This report discusses two main classes of waste. The first is logging waste. Primary manufacturing waste, the second main class,

occurs in making the logs and bolts into products like lumber, veneer, ties, and cooperage stock.[3] It also includes wood materials lost in pulping. Planing mill losses have been mainly thrown into primary manufacturing plant losses, because many sawmills have their own planing mill facilities. Secondary manufacturing waste, which is difficult to determine quantitatively, is a third source of loss. Much of it is far from the site of primary manufacture. The estimates in table 1 are confined to waste of lumber in the manufacture of furniture, millwork, flooring, etc., and in building construction. Similar losses result, for example, when paper is made into bags, towels, and boxes.

LOGGING WASTE

In 1944, logging and other woods operations in United States' forests left behind more than 3.1 billion cubic feet, or 49.0 million tons of waste. Only 6.6 percent of this quantity was used at all-- for fuel. Included in this estimate are unutilized stems 5 inches or larger in diameter at breast height; tops and limbs (tops only in softwoods) to a 4-inch minimum inside bark, and trees variously destroyed during logging and slash disposal. About 88 percent of the logging waste is from felled trees, 12 percent from damage to the residual stand. As table 2 shows, lumber log cutting wasted 2.3 billion cubic feet, or 72 percent, of the total. Most of the rest was lost in cutting pulpwood, fuel wood, and veneer logs.

Nationally we waste 69 cubic feet in logging a thousand board feet of sawlogs, 14 cubic feet per cord of pulpwood. The Pacific Northwest, however, wasted 67 cubic feet per thousand board feet of sawlogs, and 44 cubic feet for each cord of pulpwood. And in the Lake and Central Regions heavy-topped hardwoods ran woods waste to 120 to 130 cubic feet per thousand board feet of sawlogs. These figures include neither mill waste nor bark.

Table 3 shows where this logging waste occurs. Figure 2 shows regional boundaries. From 10 percent in the eastern regions to practically none in the West goes for fuel, a use that may be increased a little. In most regions the logging waste is too scattered for other purposes.

This is not true for the Douglas-fir subregion. The Pacific Northwest annually wastes 926.6 million cubic feet of wood in logging, 90 percent

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3/ Detailed statistics on logging and primary manufacturing waste and a brief summary of methods of estimating are presented in the Appendix.

Table 2.--Logging waste by principal forest products, 1944

(Million cubic feet)

Product	Parts of cut trees left in woods		Trees destroyed in logging and slash disposal		Total		Grand total
	Used for fuel	Not used at all	Used for fuel	Not used at all	Used for fuel	Not used at all	
Lumber	149.9	1,846.0	18.0	244.6	167.9	2,090.6	2,258.5
Fuel wood	..	164.4	..	35.0	..	199.4	199.4
Pulp and paper	4.2	194.6	.8	20.7	5.0	215.3	220.3
Hewed crossties	14.1	83.2	.8	9.5	14.9	92.7	107.6
Cooperage stock	4.6	67.1	.3	3.1	4.9	70.2	75.1
Fence posts	1.3	16.2	.1	1.6	1.4	17.8	19.2
Veneer	7.1	118.3	1.7	22.2	8.8	140.5	149.3
Round mine timbers	.3	19.4	.1	1.9	.4	21.3	21.7
Shingles	..	19.3	..	.7	..	20.0	20.0
Other	4.0	72.9	.4	6.1	4.4	79.0	83.4
Total	185.5	2,601.4	22.2	345.4	207.7	2,946.8	3,154.5

Table 3.--Logging waste by principal forest regions, 1944

(Million cubic feet)

Region	Parts of cut trees left in woods		Trees destroyed in logging and slash disposal		Total		Grand total
	Used for fuel	Not used at all	Used for fuel	Not used at all	Used for fuel	Not used at all	
North:							
New England	15.5	99.8	1.8	12.6	17.3	112.4	129.7
Middle Atlantic	19.5	125.8	1.5	13.8	21.0	139.6	160.6
Lake	14.8	171.6	.6	13.2	15.4	184.8	200.2
Central	20.0	264.7	.4	7.5	20.4	272.2	292.6
Plains	2.0	1.5	.1	..	2.1	1.5	3.6
Total	71.8	663.4	4.4	47.1	76.2	710.5	786.7
South:							
South Atlantic	39.8	171.3	14.1	72.1	53.9	243.4	297.3
Southeast	46.3	438.9	3.5	68.5	49.8	507.4	557.2
West Gulf	26.8	308.7	.2	50.3	27.0	359.0	386.0
Total	112.9	918.9	17.8	190.9	130.7	1,109.8	1,240.5
Total East	184.7	1,582.3	22.2	238.0	206.9	1,820.3	2,027.2
West:							
North Rocky Mtn.	..	44.0	..	15.4	..	59.4	59.4
South Rocky Mtn.	.8	13.1	..	.5	.8	13.6	14.4
Pacific Northwest	..	874.7	..	51.9	..	926.6	926.6
California	..	87.3	..	39.6	..	126.9	126.9
Total	.8	1,019.1	..	107.4	.8	1,126.5	1,127.3
United States	185.5	2,601.4	22.2	345.4	207.7	2,946.8	3,154.5

of it in the Douglas-fir subregion, west of the Cascade Divide. There an average of 2,500 cubic feet per acre cut over is lost annually; 11,500 board feet of this would make lumber. This is more volume than thousands of owners in other parts of the country have in their stands before logging.

Losses in the Douglas-fir subregion are heavy, partly because there is much breakage when large and often defective timber is clear cut on rough terrain. Power machinery drags the long heavy logs from stump to truck or railroad car, and in the process knocks over or breaks some residual timber. In this respect, donkey engines and cables are more destructive and tractors less so. In some instances tractors do only half as much damage as the donkey engines. Uncontrolled slash fires frequently kill residual timber that escapes damage by the falling of other trees and the skidding of logs. Eighty-eight percent of the logging waste in the Douglas-fir subregion is in broken-stem sections and tops of cut trees, the rest in trees broken by the heavy power machinery or burned. Studies in western Washington show that board foot logging losses are nearly three times as great in mature stands as in second growth.

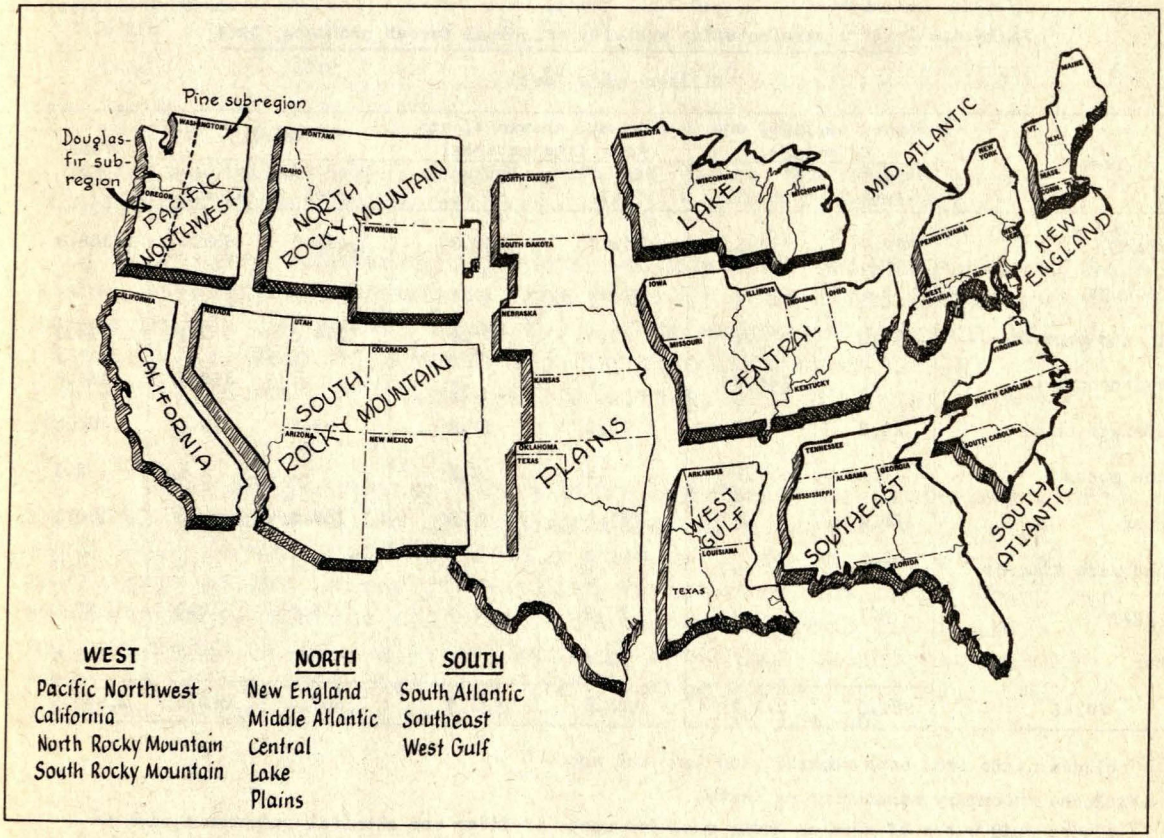

FIGURE 2.- REGIONS USED IN THIS REPORT.

There is another reason for the large waste. Industries of the Douglas-fir subregion market their products in the Eastern States. Transportation costs are heavy; rail rates on lumber shipped from Portland, Oreg., to eastern consuming centers range up to $25 per thousand board feet. West coast lumber can compete successfully in the East because it is of high quality and is mass-produced at relatively low cost by a heavily mechanized industry. This means that only the larger and higher quality material can be handled at a profit. Using the heavy equipment on small or short logs might increase unit costs and prices and thus reduce the competitive advantage of west coast products in the principal eastern markets.

PRIMARY MANUFACTURING WASTE

Large as our logging waste is, our primary manufacturing waste is greater. In brief, we lost 2.9 billion cubic feet or 44.3 million tons of wood in making the products shown in table 4. When to this figure we add the 8.6 million tons of lignin and cellulose lost in pulping, we have accounted for 49 percent (weight basis) of our total waste, as against 45 percent incurred in logging.

Table 4.--Primary manufacturing waste[1] by principal forest products, 1944

(Million cubic feet)

Product	Slabs, edgings, and trimmings		Sawdust, shavings, and other fine material		Total		Grand total
	Used for fuel	Not used at all	Used for fuel	Not used at all	Used for fuel	Not used at all	
Lumber[2]	799.7	411.8	649.3	448.0	1,449.0	859.8	2,308.8
Fuel wood	..	..	..	..	..	..	..
Pulp and paper[3]	55.0	..	59.0	..	114.0	..	114.0
Hewed crossties	..	146.6	..	..	..	146.6	146.6
Cooperage stock	24.6	3.5	11.2	11.5	35.8	15.0	50.8
Fence posts	..	.1	..	2.3	..	2.4	2.4
Veneer	51.6	.3	57.7	.5	109.3	.8	110.1
Round mine timbers	3.4	.4	..	..	3.4	.4	3.8
Shingles	2.1	.8	10.9	11.4	13.0	12.2	25.2
Other	47.6	7.7	35.4	17.9	83.0	25.6	108.6
Total	984.0	571.2	823.5	491.6	1,807.5	1,062.8	2,870.3

1/ Includes waste from both domestic and imported wood.

2/ Excludes secondary manufacturing waste.

3/ Includes only waste of wood as such; excludes waste of fiber and chemical components such as lignin, sugars, and hemicelluloses.

Table 5.--Primary manufacturing waste[1] by principal forest regions, 1944

(Million cubic feet)

Region	Slabs, edgings, and trimmings		Sawdust, shavings, and other fine material		Total		Grand total
	Used for fuel	Not used at all	Used for fuel	Not used at all	Used for fuel	Not used at all	
North:							
New England	46.4	9.7	30.8	16.1	77.2	25.8	103.0
Middle Atlantic	44.1	17.2	23.4	31.4	67.5	48.6	116.1
Lake	39.2	12.5	10.4	18.4	49.6	30.9	80.5
Central	45.4	30.6	5.9	33.6	51.3	64.2	115.5
Plains	1.7	..	1.0	.3	2.7	.3	3.0
Total	176.8	70.0	71.5	99.8	248.3	169.8	418.1
South:							
South Atlantic	164.1	43.2	78.2	107.8	242.3	151.0	393.3
Southeast	185.4	198.5	138.4	116.1	323.8	314.6	638.4
West Gulf	120.9	116.7	95.2	37.7	216.1	154.4	370.5
Total	470.4	358.4	311.8	261.6	782.2	620.0	1,402.2
Total East	647.2	428.4	383.3	361.4	1,030.5	789.8	1,820.3
West:							
North Rocky Mtn.	17.8	26.5	20.8	32.5	38.6	59.0	97.6
South Rocky Mtn.	9.9	5.8	6.6	9.8	16.5	15.6	32.1
Pacific Northwest	281.2	67.3	340.7	69.9	621.9	137.2	759.1
California	27.9	43.2	72.1	18.0	100.0	61.2	161.2
Total	336.8	142.8	440.2	130.2	777.0	273.0	1,050.0
United States	984.0	571.2	823.5	491.6	1,807.5	1,062.8	2,870.3

1/ Includes waste from both domestic and imported wood. Excludes waste of fiber and chemical components such as lignin, sugars, and hemicelluloses by the pulp and paper industry.

Primary manufacturing waste includes: (1) Coarse material like slabs, edgings, and trimmings from sawmills, cores and trimmings from veneer mills, and culled stave bolts from cooperage stock mills; (2) fine material such as sawdust and shavings from sawmills and other plants; (3) fibers and chemical components lost in making pulp and paper.

That 63 percent of the primary manufacturing waste was burned for fuel illustrates its great commercial advantage over logging waste (6.6 percent used for fuel): much of it is concentrated, often near large cities, where it may find various markets or at least (as with shavings, sawdust and other fine material) heat the boilers of the producing mill. Only the Central States and the Northern Rocky Mountain Region used less than half of this waste for fuel. Table 5 shows where the primary manufacturing waste is located.

The small eastern logs yield such a high volume in slabs, edgings, and other coarse waste when sawed for lumber or used for veneer or similar products that coarse waste exceeds fine everywhere east of the Plains. Just the opposite is true in the western regions, however, where big logs predominate.

The following discussion of our primary manufacturing waste supplements the basic statistical data contained in tables 4 and 5, and in the Appendix.

Lumber

Considering the amount and nature of the product, it is not surprising that 2.3 billion cubic feet, or 80 percent, of our primary manufacturing waste comes from the manufacture of lumber. Sawmills and

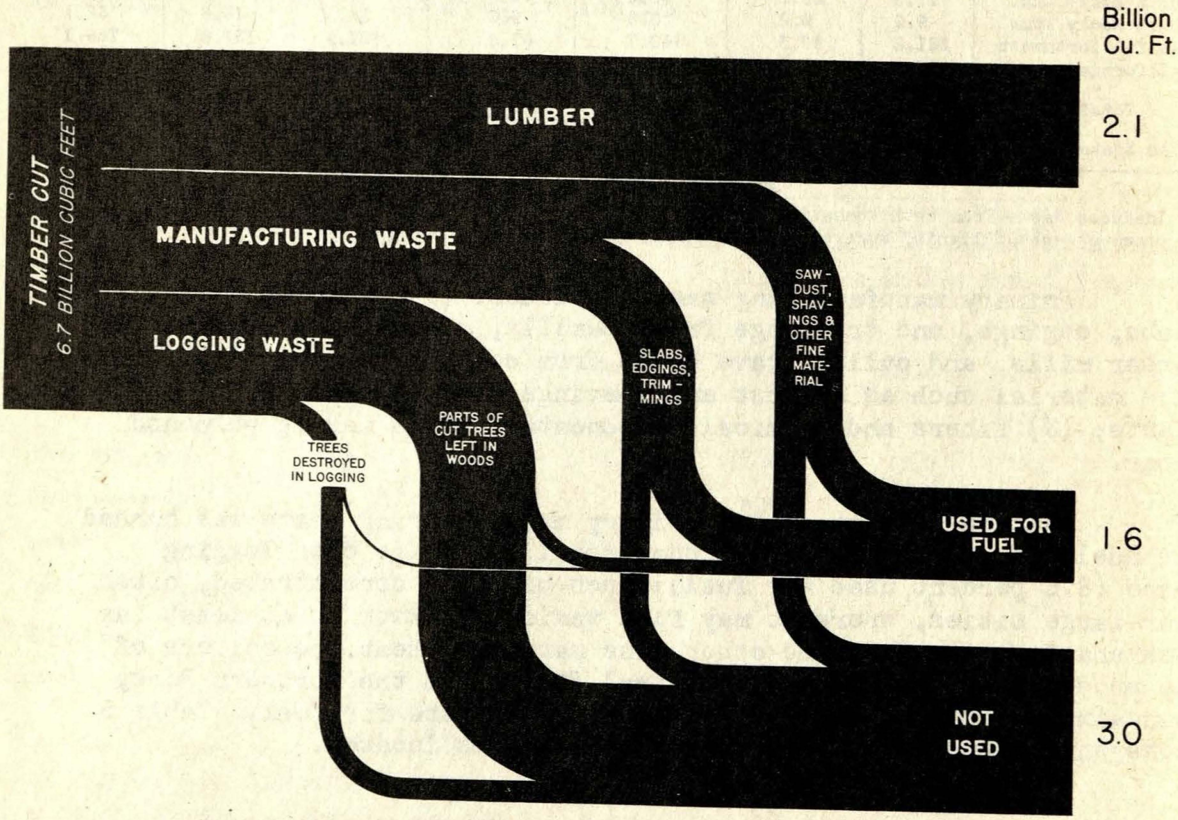

FIGURE 3.- USE AND WASTE OF TIMBER CUT FOR LUMBER, UNITED STATES, 1944.

planing mills account for 90 percent of our primary manufacturing waste in the West, 75 percent in the East. They average 70 cubic feet of waste per thousand board feet of lumber sawed--37 cubic feet of coarse material and 33 of fine. The final disposition of all timber cut for lumber is graphically shown in figure 3.

Not all of this waste is concentrated. In the eastern regions the small portable mills that cut much of the lumber operate in the woods and move frequently, thus leaving a considerable amount of waste unused and widely scattered. Larger, permanent mills are frequently located in or near towns and have a ready market for their waste.

Sawmilling practices affecting waste vary so considerably over the country that a brief description of them in some of the more important regions follows:

New England and Middle Atlantic

Total sawmilling waste in the New England and Middle Atlantic Regions was 140 million cubic feet in 1944, largely from small mills. In 1942 some 6,300 sawmills in these regions produced 2.5 billion board feet of lumber, but only 29 sawed more than 5 million board feet each in that year. Over half sawed less than 200 thousand board feet. Furthermore, concentration yards for drying and surfacing the lumber are uncommon. Thus the sawmill waste is widely scattered. About three-fifths of it was burned for fuel. Opportunity for reducing this mill waste is limited largely to more efficient sawing and machine operation to get a greater yield of lumber from a given log volume.

South Atlantic

Of the 334 million cubic feet of sawmill waste in the South Atlantic Region, 200 million were used for fuel in 1944. The region is characterized by small portable mills which saw rough lumber and haul it to a concentration yard for planing and air-drying. A few large mills surface their own lumber. This concentration yard waste holds the greatest possibility for conversion to chemical or other products. It usually is easily accessible by road or rail. Being mostly shavings, it can be handled mechanically--loaded and unloaded by blowers, and hauled by 5-ton trailers and $1\frac{1}{2}$- or 2-ton trucks. In 1944 an average truck haul of 10 miles cost 99 cents per ton. Rail transportation costs on loose shavings ranged from $1.36 per ton for a 20-mile haul to $2.07 for 60 miles.

Small sawmills produce about 95 cubic feet of waste per thousand board feet of pine lumber, according to 1944 studies in North and South Carolina. About three-fourths of this is at the widely scattered mill sites in or near the forests. The remaining one-fourth, mostly shavings, half of which was used for boiler fuel and other purposes, is at

concentration yards. A domestic fuel wood market exists for much of this slab and fine waste. Local prices in 1944 were between $2 to $6 per cord at the mill site. (See p. 20.)

Southeast and West Gulf

Sawmill waste in the Southeast and West Gulf Regions aggregated more than 767 million cubic feet in 1944. In character and distribution it does not differ greatly from that in the South Atlantic Region.

In the West Gulf Region 15 to 20 larger sawmills still cut over 25 million board feet each per year, thus concentrating considerable mill waste. Only 88 million cubic feet of sawmill and planing mill waste are unused, but 174 million cubic feet are burned for fuel in plants that could convert to gas or oil if profitable wood waste markets can be developed. Chances for establishing waste-using industries in this region are good. (See p. 20.)

Lake States

Lumber manufacturing waste in the Lake States totaled 48 million cubic feet. In this region the large and moderately large sawmills are rapidly passing, and with them the most favorable opportunity to utilize large quantities of convenient waste. The remaining large sawmills have, for the most part, enough stumpage for only a few years, and the waste from smaller scattered sawmills is and will continue to be costly to handle. The Lake States have made considerable progress in using waste but still more can be utilized. Much of it should be marketable at the nearby consuming and manufacturing centers around Chicago and Detroit. The Chicago area manufactures large quantities of roofing felts and papers, commodities that are taking increasing amounts of wood. (See p. 22.) The fruit growers and farmers of the Lake States also provide a ready market for the boxes, crates, and small dimension stock which can be made at least in part from waste or low-grade wood.

Northern Rocky Mountain

The sawmill waste in the Northern Rocky Mountain Region was 94 million cubic feet in 1944. About 70 percent of the lumber was produced by mills cutting over 10 million board feet. The fact that this mill waste is so concentrated enlarges the possibilities of utilizing it.

In the larger mills, about 67 percent of the average ponderosa pine sawlog goes into lumber, 2.4 percent into lath, 1.2 percent into molding and short box--a total of 70.6 percent for manufacture. Three percent is sold for fuel and 13.5 percent fuels the mill. Only 13 percent is not used at all. By comparison, a small mill (cutting under half a million board feet of lumber yearly) would use only about 61 percent of the same log for lumber; the remaining 39 percent would be waste.

Consumption of wood fuel is high in this region of long, cold winters and expensive coal. Even so, only 40 percent of the mill waste is used for domestic and industrial fuel. Because the region is sparsely populated, it must find outside markets for its products. However, unless present high freight rates on outgoing shipments are modified they may definitely limit the establishment of industries based on wood waste.

Pacific Northwest

Prospects for increasing consumption of primary manufacturing waste are brightest in the Pacific Northwest Region where large volumes of the waste are concentrated in or near industrial centers. Furthermore, the growing western population will tend increasingly to draw on local products.

Pacific Northwest sawmills in 1944 wasted 663 million cubic feet of material--62 cubic feet per thousand board feet of lumber. Over 40 percent of the total sawmill waste was burned to power the mills, but more and more mills are buying electric power.

At present, waste from sawing lumber goes chiefly into fuel, pulpwood, and lath. In 1944, 13 million cubic feet was sold to pulp mills: 66 percent as chipped wood, and the rest as slabs, edgings, and trim. The bulk of this was western hemlock, along with smaller quantities of Douglas-fir, white fir, and Sitka spruce. The use of Douglas-fir for wood pulp appears to be increasing, but sales of sawmill waste in the immediate future may not keep up to the high 1944 levels. In addition 3-3/4 million cubic feet of sawmill waste was sold for lath, cut-up stock, and miscellaneous byproducts.

Pulp and Paper

The waste of dissolved substance (excluding that recovered as byproducts but including that used as fuel) comprising lignin, cellulose, sugars, and other chemical components and wood fiber in the manufacture of pulp and paper in 1944 totaled approximately 8.6 million tons. This equals about 48 percent of the wood consumed and represents about 83 percent of the entire loss of wood in its conversion to pulp

and paper. The remaining 17 percent resulted from wood losses in storage and in preparation for pulping.

Dissolved substances in the spent liquors from the chemical pulping processes made up by far the largest portion of the waste of chemical components (7.9 million tons). Fiber waste in mill effluents totaled 0.54 million tons, and dissolved substances from pulp bleaching 0.15 million tons. Most of the 5.2 million tons of wood substance lost in pulping of wood by the sulfate and soda processes was burned as fuel. A large part of the remaining 3.4 million tons was discharged into waterways, often causing serious pollution.

Pulpwood

In 1944 the United States pulp and paper industry consumed 16,757,000 cords of domestic and imported pulpwood. Some wood waste resulted from the storing and preparing of this wood for pulping. Although accurate information is not available, it is estimated that this waste totaled about 114 million cubic feet, or 8 percent of the wood consumed. It resulted chiefly from (1) decay in storage, (2) cull material, (3) removal of bark, and (4) fines resulting from chipping.

Decay in storage occurs principally in the Northeast, the Lake States, and the Appalachian regions, where pulpwood is normally stored for 6 months to a year. Depending on temperature, humidity, ventilation, and length of time in storage, normal annual storage loss in the northern regions varies between 3 and 10 percent. In 1944 the average storage period was probably shorter than usual, hence decay should have been small, perhaps not more than half the normal annual loss.

Before pulping, operators normally sort out sticks that are heavily decayed, excessively crooked or knotty, of undesirable species, and, in some parts of the South, that contain charred turpentine faces. In 1944, however, pulpwood was so scarce that nearly all that was available was used, to the detriment of the quality of the paper produced. Thus 1944 cull, including cull material received for storage and subsequent decay in storage, probably did not exceed 55 million cubic feet, 4 percent of the 16-3/4 million cords consumed. Most of the cull was used for fuel.

Roughly 12 to 15 percent of the volume of unbarked wood received at the pulp mill is bark, which is usually removed before pulping either by knife barkers, barking drums, or hydraulic barkers. Pulpwood can be barked by hand in the woods, but in 1944, because of the labor shortage, about 90 percent was barked at the mill. All barkers waste some wood--hydraulic barkers the least, knife barkers the most. This loss is estimated at 2 percent of the volume of the wood after barking, or nearly 25 million cubic feet. As it comes from the barkers the bark is often saturated with water. Heavy pressing reduces the moisture

content enough to give the bark nearly half the heat value of low-grade lignite coal, most of the bark is used as fuel by the pulp mills, but some of it has more efficient uses. (See p. 23.)

When pulpwood is chipped for chemical pulping, quantities of fine material are produced--sawdust-like fines, pin chips, and a few slivers. Normally, this material is not used for pulp, but is burned with other refuse as fuel. The quantity varies between 1 and 8 percent of the wood chipped. An average of 3 percent would mean a loss of about 35 million cubic feet. Pulp from chips containing much of this fine material is normally dirty and unfit for exacting use. Some of it, however, can be used for corrugating board, mill wrap, coarse paper, and boxboard.

Dissolved substances

Sulfate pulping waste.--In the manufacture of sulfate wood pulp, chips are treated in large steam-heated digesters at high temperature and pressure. The alkaline cooking liquor separates the cellulose fibers by dissolving the lignin bonding material.

During 1944 we used about 6.8 million cords of pulpwood to make 4.5 million tons of sulfate pulp (air-dry basis) recovering as pulp 47 percent of the wood treated and leaving 4.7 million tons of dissolved substances in the spent cooking liquor. Over half of the wood substance in the spent liquor, at present used chiefly for fuel, is lignin. However, small quantities are put to minor commercial use and other outlets are being explored.

Tall oil and turpentine are commercial byproducts in the manufacture of sulfate pulp. Refined tall oil products are used chiefly for soaps and as drying oils for paint. Tall oil itself is a variable mixture of fatty and resinous acids and unsaponifiable compounds occurring in pine wood. It can be recovered at the rate of 0.03 ton per ton of sulfate pulp produced. Thus 136,000 tons could have been produced in 1944. Actually only 80,000 tons were recovered; the 56,000 tons wasted was burned with the spent liquor as fuel.

Sulfate turpentine can be condensed from the digester gases at the rate of 0.033 barrel per ton of pulp. In 1944, out of a possible 150,000 barrels (54 million pounds) we salvaged only 104,307 barrels (38 million pounds) and burned the rest as fuel.

Sulfite pulping waste.--In manufacturing 2,386,149 tons (air-dry) of sulfite pulp in 1944, we lost 2,468,000 tons of wood substances, oven-dry basis, dissolved in the cooking liquor. Fifty-two percent of the weight of the processed wood was dissolved in the waste liquor and 3 percent passed off in condensable and noncondensable gases.

The principal constituents of sulfite waste liquor and their relative proportions of the total dissolved solids are: Lignin, 65 to 70 percent; wood decomposition products like sugars and resins, 20 to 30 percent; and unconsumed calcium bisulfite, 6 to 10 percent. Owing to the difficulties of converting these substances into usable form, very little use is made of sulfite waste liquor. Much is dumped into streams, frequently causing pollution. Small quantities, possibly as much as 10 percent of the waste liquor available, have well-established uses--as a constituent in linoleum cement, a core binder in foundries, an ore binder, and a road binder.

The heat value of the dissolved solids in sulfite waste liquor equals that of low-grade lignite coal. Burning evaporated liquor appears to be the most effective means of disposal and of recovering some value from all the liquor. An installation for this purpose is now being made in the United States for magnesium bisulfite liquor. Alcohol, yeast, and a fungus protein food have been made on a commercial basis from the wood sugars in sulfite waste. (See p. 25.)

Soda pulping waste.--During 1944, 510,000 tons of wood substance, oven-dry basis, was dissolved in the cooking liquor in producing 412,755 (air-dry) tons of soda pulp. The yield of soda pulp was 44 percent of the weight of the wood used. Most of the loss was lignin dissolved in the spent liquor and burned in the recovery process. Small quantities of activated charcoal were prepared from the lignin and a little lignin was recovered for other uses.

Groundwood and other high-yield pulping wastes.--Groundwood or mechanical pulp is made by pressing wood against the roughened surface of a revolving grindstone. This stone revolves partially immersed in a slurry of pulp. Water added during grinding absorbs the heat generated by friction and washes the pulp. Waste from this process in 1944 was 51,000 tons (oven-dry), or about 3.5 percent of the pulpwood used. This waste was chiefly water-soluble constituents including easily soluble hemicelluloses, mineral salts, and other materials at such low concentration that recovery is impractical.

High-yield or semichemical pulps are produced by partially cooking chips in water, steam, or chemical solutions followed by fiberizing in attrition mills and by other methods. In 1944 the amount of wood substance dissolved in the cooking liquors used in producing 1,021,200 tons (air-dry basis) of semichemical and other high-yield pulps was approximately 216,000 tons (oven-dry).

Fiber losses

In the manufacture of pulp and paper in 1944, approximately 540,000 tons of fiber were carried in the effluents from the various washing, dewatering, and sheet-forming operations in which the fibers

are filtered from a water suspension on a fine-mesh wire screen. The water draining through the screen contains a small quantity of fibers and other materials which pass through the screen openings. This "white water" is returned to the system and re-used in varying amounts to avoid loss of fiber and other materials. In most mills, however, all the white water cannot be used in this way. The remainder, usually after some treatment to recover the fiber, passes into the mill effluent water, carrying some residual fibrous material with it.

Of these losses, 282,000 tons result from paper making. The 258,000 tons from pulp manufacturing were distributed among the pulping processes as follows: Sulfate, 114,000 tons; soda, 14,000 tons; sulfite, 72,000 tons; groundwood and other, 58,000 tons.

Bleaching losses

Actual losses in bleaching pulp in 1944 are estimated at 148 thousand tons. This waste includes a residue of brown-colored lignin from the wood, and also a small amount of other colored noncellulosic material. The lignin content of unbleached pulp ranges from about 1.5 to 6.0 percent. In pulp bleaching these residues are destroyed. In addition, however, some of the less resistant hemicelluloses are removed in bleaching, and some fibers are lost in washing the pulp.

Hewed Crossties

About 40 percent of the crossties now being laid are hewed and 60 percent are sawed. The waste from sawing ties is included in sawmill waste, for they are normally cut by mills that could or do produce lumber. Ninety-nine percent of the hewed ties are made east of the Plains and 82 percent in the Southeast and West Gulf Regions. Nearly 60 percent of the hewed ties are of hardwood species.

A majority of the 34.1 million hewed ties produced in 1944 were standard ties 7 by 9 inches in cross section and 8 or 8½ feet long. Ties are normally hewed in the woods, preferably from tall slender trees 14 to 16 inches in diameter that will yield 3 to 5 ties without excessive hewing. Although ties are hewed in the woods and not in a plant, the resultant waste is actually a processing loss. This processing loss, accounting for 55 percent of the volume of the average tie log cut, aggregated 146.6 million cubic feet in 1944, exclusive of the loss in top stems and culled mainstem sections included in logging waste. None of the estimated 4.3 cubic feet of chips per tie are used now and because of its scattered occurrence very little of this waste is likely to be used.

Veneer

Most veneer is made by rotating short logs against a heavy knife which peels off the veneer in a continuous sheet. Small quantities of high-grade veneer are cut into thin slices either by a knife or very thin saw. Waste in the manufacture of veneer amounts to 110 million cubic feet, 99 percent of which is used as fuel.

Waste in the manufacture of rotary cut veneer is in central cores too small in diameter to be cut by the knife, in trimmings to remove checks and blemishes in the veneer, and in scraps made in "rounding up" the bolt. In some places the cores are used for making 2 x 4's, crating, and pulpwood. Sixty-two percent of the veneer is manufactured in the East, which produces all the hardwood veneer. Approximately 90 percent of the softwood veneer is from the West, nearly all from the Pacific Northwest.

Cooperage Stock

Cooperage stock is of two kinds, tight for barrels and kegs that contain liquids, and slack for nonliquids like vegetables, fruit, and nails.

Tight cooperage stock is almost exclusively cut from one of the white oaks. The staves are usually made on a barrel saw--a rotating steel cylinder the diameter of a barrel with sawteeth on one rim. Billets already trimmed to stave length are pushed into the saw and thus cut to the curvature of the barrel. The staves are air-dried and then sent to a finishing plant where they are smoothed and shaped into barrels. The waste at a tight stave mill is largely sawdust, edgings, and knotty, defective, or split pieces. Most of the waste in making heading is from trimming the squared boards to make round heads, and from cull pieces. Cooperage waste is used as fuel and this use could be expanded.

Slack cooperage stock is usually made by slicing staves from billets, chiefly pine or gum, with heavy mechanical knives. The crude staves are kiln- or air-dried and then culled. Most of the waste in slack stave mills is from culling. Slack heading is made in the same way as tight heading. In general, requirements for slack staves and heading are not so rigorous as for tight, and waste is usually not so great.

The total processing waste in cooperage stock manufacture is 51 million cubic feet, the largest part of which is coarse material. The bulk of this volume is cull billets and staves that are used for fuel. Ninety-five percent of the cooperage stock is manufactured east of the Plains, 65 percent in the Southeast and West Gulf Regions. Hardwood species make up 77 percent of all cooperage stock.

Shingles

Shingles are usually made of some species of cedar. Ninety-seven percent of them are made in the West, chiefly in the Pacific Northwest.

Bolts of shingle length are cut from logs at the shingle mill. The bolts are usually quartered for ease of handling and to give the greatest possible number of vertical-grained shingles. The resulting billets are then sawed into shingles by a circular saw equipped with a frame that automatically shifts the billet into position for the next cut. Since the saws are usually thick and the shingles thin, most of the 25.2 million cubic feet of waste in shingle mills is sawdust and a fuzz called shingle-tow. Half of this waste is burned for fuel.

Other Primary Manufacturing Waste

Waste in the cutting of such items as sporting goods, bobbin and gunstock blanks, shuttle and shoe last blocks, round mine timbers, and fence posts aggregate 115 million cubic feet. Many of these items are made from several so-called specialty species under widely varying conditions. No separate treatment will be given to individual items. Most of this waste is used as fuel and some of the remainder could be so used.

Table 6.--Logging and primary manufacturing waste in relation to total commodity drain, by principal forest products, 1944

Product	Waste			Total commodity drain	Waste as a percent of drain		Actual product as a percent of drain
	Used for fuel	Not used at all	Total		Used for fuel	Not used at all	
	Million cu. ft.	Million cu. ft.	Million cu. ft.	Million cu. ft.	Percent	Percent	Percent
Lumber[1]	1,616.9	2,950.4	4,567.3	6,711.1	24	44	32
Fuel wood	..	199.4	199.4	2,202.8	0	9	91
Pulp and paper[2]	109.6	215.3	324.9	1,306.3	8	17	75
Hewed crossties	14.9	239.3	254.2	363.5	4	66	30
Cooperage stock	40.7	85.2	125.9	173.8	23	49	28
Fence posts	1.4	20.2	21.6	219.9	1	9	90
Veneer	118.1	141.3	259.4	391.7	30	36	34
Round mine timbers	3.8	21.7	25.5	225.0	2	9	89
Shingles	13.0	32.2	45.2	71.7	18	45	37
Other	87.4	104.6	192.0	515.8	17	20	63
Total	2,005.8	4,009.6	6,015.4	12,181.6	16	33	51

1/ Does not include waste in the remanufacture of lumber into furniture, construction, etc., estimated as 463 million cubic feet, all presumed to have been used for fuel.

2/ Includes only waste in form of wood; excludes waste of fiber and chemical components. Does not include waste in processing imported pulpwood, estimated at 9.4 million cubic feet.

Table 6 summarizes the information on wood waste given in preceding sections and shows how much of the total commodity drain on our forests survives logging and primary manufacture. Not all of this wood waste is of a size and quality, and in sufficient concentrations to warrant utilization under present economic conditions.

The bulk of the wood waste concentrated at or near potential centers for waste-using industries is found in the West and the South. These regions are, therefore, the likeliest places to locate waste-using plants. In both regions the aggregate quantity of waste is great. It seems possible to maintain in these regions, therefore, a permanent group of primary industries. This is an important factor because waste-using industries cannot yet pay for carrying charges on land and timber and for logging and transportation improvements. A temporary sawmill operation is no basis for a waste-using industry. Hence primary industries must bear the brunt of the costs of growing and harvesting timber, allowing the waste-using industries to get their raw material cheaply.

Sawmill waste, since it is already partly concentrated, appears the most promising source of raw material for such industries, partly because markets often can be found for them in the vicinity of the mill. The Douglas-fir subregion, for example, draws from mill waste nearly 13 million cubic feet of its annual consumption of 225 million cubic feet of pulpwood. A growing western population affords a growing market for the products waste-using industries can furnish and needs the employment provided by these industries.

In the West Gulf Region 15 to 20 large sawmills still cut more than 25 million board feet each per year, thus concentrating considerable waste. Indeed, although it has only about 88 million cubic feet of unutilized sawmill and planing mill waste, this region probably offers the best opportunity in the entire South for establishing industries based on wood waste. Natural gas or oil would often make cheap substitutes if the 174 million cubic feet of sawmill waste now burned as fuel could find profitable markets.

In both West and South some mill waste now burned for fuel could be more efficiently utilized. (The Pacific Northwest burns more than 80 percent of its sawmill waste for fuel, much of it in domestic use.) Where species which now fuel mill boilers can be chemically utilized, the mill can often shift to other sources of power. Wherever electricity is cheap, as in parts of the West, or where low-cost natural gas is available, as in parts of the South, industrial wood fuel can practicably be replaced. Preliminary studies during the war period indicate that wherever sawmill or concentration yard operators in such

areas can get as much as $1.75 per ton for hogged fuel, shavings, and sawdust f.o.b. producing mill, they might advantageously convert to electricity or gas fuel.

Progress toward more complete wood utilization is made by putting to use material at present unutilized and by turning material now going into low-quality uses to as high a use as its quality and the economic conditions permit. Better utilization of wood waste is discussed under three heads: Physical, chemical, and fuel uses.

PHYSICAL USES

Logging Waste

The Douglas-fir subregion, of course, offers our best chance to reduce logging waste. Its 11.5 thousand board feet of waste per acre should not go unclaimed for long. Indeed, progress is being made in this direction. Where tractors have replaced donkey engines for skidding logs to loading points, losses from broken or knocked-over trees have been cut considerably, sometimes reduced by half. Tractors and donkey engines, as well as other equipment, are being made light enough to handle efficiently the small, short logs that heavy machinery could not profitably work. Portable chippers have been developed experimentally. Set up in the woods, they convert logging waste to chips which can be loaded mechanically for transportation to consuming plants.

Capitalizing on logging waste in this region seems also to hinge on the operator's ability to log and market more than one product at a time, on finding cheaper ways of handling small or broken stuff, and on developing products whose profit margins are big enough to absorb the costs of logging what is now wasted. Actually, some out-of-pocket cost in reducing logging waste is justifiable, for fire hazards, and consequently the charge for protection, are also thereby reduced.

Some defective hemlock logs formerly left in the woods now go to pulp mills. Portable sawmills are beginning to utilize the waste left by the power loggers. Being close to woods operations, they can saw rough lumber or cants from small or defective logs without hauling slabs and waste very far. Some companies are "prelogging" and "relogging" with lighter equipment in order to reduce logging waste.

Sawmill Waste

A large volume of mill waste can be made into specialized wood products. For example, sawing of logs with crook or sweep and trimming of defects results in many short pieces that cannot be sold as lumber. Often such pieces of wood waste are

discarded. Yet they would make dozens of articles that are now generally cut from standard-length lumber--handles, chair spindles, flooring, lath, toys, molding, stepladder parts, to name only a few.

In some parts of the country a flourishing business has developed in dimension stock and squares, pieces of wood cut to approximate dimensions of the finished piece for further manufacture into small items that need not be made from standard-length lumber. For example, a piece of dimension stock for a table leg would be as long as the leg and just thick enough to permit turning the leg. Large quantities of such pieces for chair rounds, drawer fronts, toys, woodenware, etc., could be made at the primary manufacturing plant from both hard- and softwood waste. Opportunities are excellent for increasing these uses of coarse waste.

Weather boarding, siding, and sheathing, as well as flooring and subflooring, are always manufactured in standard lengths, although they are nearly always nailed to studding or joists spaced 16 inches on center. Considerable thought has been given to the possibility of manufacturing panels from lumber cut in multiples of 16 inches in length, to be nailed to the standard-spaced joists and studding. Large quantities of waste could be effectively used in this way.

The great volume of box and crating stock we consume annually is also of such dimensions that more of it than at present could be made from waste and low-grade material.

Some forest and mill waste, including slabs and edgings with or without bark, is shredded by mechanical "defiberators" into a rather coarse fiber used as a filler in rolled roofing, building felts, and composition shingles. Chemical pulp is also used to some extent. In prewar days roofing felt was only 10 to 15 percent wood fiber. Rags were used extensively. However, rags were in short supply during the war and wood fibers were successfully substituted. Now up to half of the felt may be wood fibers, and this proportion will probably remain or increase. It is doubtful if rags will again be able to compete for this market.

Various defiberized wood products appear as building boards, either as all-wood products or in mixture with other materials. The following tabulation shows how rapidly building board production has risen in late years:

	Tons
1935	80,000
1936	99,000
1937	110,000
1938	118,000
1939	115,000
1940	180,000
1941	932,000
1942	1,052,000
1943	1,064,000
1944	1,088,000

As high-quality timber becomes scarcer, the use of short-length waste for squares, small dimension stock, and fiber board will very likely increase. It has already done so in the North where the supply of good timber is greatly reduced. In addition, there will be an increased use of fine waste, in the form of shavings, sawdust, and wood flour for bedding, insulation, explosives, plastics, and similar products.

Pulpwood Waste

Pulpwood creates much physical waste that could be reduced or utilized. Some of the millions of cubic feet that spoiled in storage could have been saved by improved storage practices. Storage yards should be well-drained and cleaned of bark, leaves, and other material from which infection might spread. Clean earth will serve, but gravel, cinder, or slag surfaces are better. The logs and billets should be piled off the ground in open ricks on uninfected stringers.

Some pulpwood bark can be more efficiently used than for fuel, although not much of it is. That of some species yields tannin. (See p. 31.) The corky portion of Douglas-fir bark, when ground, could be used for bottle cap liners, floats, and gaskets. The bark of most species can be chipped for insulation or as a sound deadener. Bark might also be used in the manufacture of roofing felts, sheathing, carpet liners, bottle wrappers, deadening felts, chipboard, and boxboard.

Cull wood can be used for the manufacture of boxboard, roofing felt, building papers, and insulating board. Whenever substantial quantities of cull or of wood with the bark on are available, it can be used for fiber products--building, corrugating, and low-grade container board--which, although of low-quality, might return more than the fuel value of the wood.

CHEMICAL USES

The broken stem sections, tops, and limbs that are part of the yield of every forest will never make such products as lumber, cooperage, veneer, or poles. Chemical conversion, however, should provide a means of using at least some of these little-used portions of the wood crop. The most important limitation is the cost of gathering and hauling the wood, for plant and manufacturing costs are usually high in chemical industries using wood, and often their products must compete with those from other cheap raw materials.

To keep raw material prices down, then, chemical uses must be correlated with the manufacture of wood into lumber, veneer, and similar products, so that these principal products can carry the major share of the costs of growing and harvesting the logs. In these circumstances chemical utilization becomes a valuable factor, taking its

raw material from low-quality trees and parts of trees and from the inevitable mill waste incident to the manufacture of other timber products.

Present indications are that chemical industries can expand, and that their demand for wood, especially in the West and South, could increase substantially in the next two or three decades.

Various wastes, byproducts, and low-quality trees are already being used by a number of companies. In the West Gulf Region one lumber company operates a pulp mill and a hardwood distillation plant, as well as a sawmill. Because the company can take the crop as it grows, or at least approach that ideal, its forest-management costs go down when utilization of logging waste reduces fire hazard and makes it easy for the forest to reproduce itself. Furthermore, cutting the slow-growing and inferior trees steadily improves the composition of the forest. Several other companies have moved or are moving toward such diversified and integrated utilization.

Other advantages accrue to diversified forest use, among them a flexibility impossible in a single-product wood industry. In diversified use the plant operator asks what industries can be based upon the forest, not merely how many sawlogs he can obtain from it. In brief, diversified utilization is the antithesis of the high-grading type of cutting that has been applied to so much of our forest in the past.

Four primary chemical industries fit into a diversified program: pulp and paper, wood distillation, wood hydrolysis, and tannin.

Pulp and Paper Industry

Of these four primary chemical industries that fit into a program of diversified use of forest products pulp and paper manufacture is the most important. Nevertheless in some parts of the country lack of integration of this industry with sawmilling, for example, leads to inadequate use of wood. Even in the West Gulf Region the well-developed pulp industry has not yet been integrated with the sawmills to the extent possible and desirable. In this connection it is of interest to note that Sweden in 1937 made 25 percent of its pulp from sawmill waste. Over 90 percent of the Swedish lumber industry's solid waste, excluding bark and sawdust, ended up in pulp mills. To be sure, in Sweden large sawmills and pulp mills almost always operate together near the mouths of driveable streams, while in our own South pulp mills are not usually adjacent to sawmills. Nevertheless it should be possible to bark more slabs and trimmings at sawmills and convert them into chips. Such chips can be loaded and unloaded cheaply by blowers and should give pulp mills a new wood supply.

Pulp mills can take at least part of their wood from the thinnings and improvement cuttings in forests under intensive management, and from those portions of the final harvest unsuited for high-quality products. Considerable progress is being made in trading logs between sawmills and pulp mills and in relogging for pulpwood defective and inferior trees on areas previously cut for lumber. Then, too, we are now learning to pulp so many species of wood that we should be able to make wide use of forest and mill waste. The present trend is toward expansion in production of corrugated, insulating and building board and other coarse fiber products from wood waste by the semichemical process.

If a given mill turns out various kinds of pulp and paper products it can select the best wood for the most exacting requirements and use low-quality and cull wood for papers for which they are suited. Wood of lower quality can be used for bleached pulp than for some unbleached pulps, because bleaching eliminates some dirt-producing materials.

Possibilities for reducing the greatest waste in the manufacture of pulp and paper, the dissolved wood substance in chemical pulping liquors, are indicated by present trends in two directions. In the production of high-yield pulps with only partial removal of lignin, the pulp yields may be as much as 50 to 60 percent higher than the yields from conventional chemical pulping processes. Other possibilities not as yet applied commercially for improved yield of chemical pulp essentially free of lignin lie in milder chemical processes that give a more selective removal of lignin with less destruction and solution of cellulosic material. Fully bleached semichemical pulp obtainable in yields of about 60 percent of the weight of the wood or about one-third higher than the yield of fully bleached pulp of the usual type is an example of such a process.

Ethyl alcohol has, for a number of years, been manufactured in European mills from the fermentable sugars in sulfite waste liquor. Alcohol plants installed during the war in one Canadian sulfite mill and one United States sulfite mill are now operating. At an estimated production of 20 gallons of alcohol (95 percent strength) per ton of softwood sulfite pulp, we could have made a theoretical 40 to 45 million gallons of alcohol in 1944. Converting the fermentable sugars in softwood sulfite waste liquor would utilize about one-fifth of the wood substance in the liquor and reduce the stream pollution effect by about half.

Yeast and a fungus protein derived from wood sugars provided an important amount of human and animal protein food in Germany during the late war. About half of this protein was made from the sugars in sulfite waste liquor, but it can also be made from sugars formed in wood hydrolysis. About 30 percent of the wood substance in sulfite waste liquor can be used for yeast production. Techniques now known recover 226 and 162 pounds of yeast per ton of sulfite pulp from

beech and western hemlock, respectively. The dried yeast is about half protein. For over 10 years bakers' yeast has been made in two Canadian plants from sugars in sulfite waste liquor supplemented with molasses.

Wood Distillation Industry

This term covers (1) destructive distillation of hardwoods, (2) destructive distillation of softwoods, and (3) steam and solvent treatment for softwoods. In destructive distillation, hardwoods and softwoods are heated to high temperatures in a partial absence of oxygen. Charcoal is the final nonvolatile product; the volatile products are partly condensed, collected and used, and partly lost. When treated with steam and solvent, chips from pitchy longleaf and slash pine stumps and stems yield turpentine, pine oil, and rosin. All steam and solvent distillation plants are in the Southeast.

Although these processes are themselves sometimes wasteful, all three of them can use wood that would otherwise go to waste. Because they take qualities and species of wood that are of little or no use for products like lumber, they can remove from the forest wood that interferes with the crop trees. This is especially true of the plants that distill hardwoods.

Destructive distillation of hardwoods

The charcoal market is the key to the future of the hardwood distillation industry. For many years operators derived only charcoal from the wood they piled under turf and incompletely burned. Later closed retorts were widely used. They permitted the recovery of volatile substances, acetic acid, acetone, and methanol. By 1904 the industry had developed into a large and efficient business that used a million cords of wood annually. It held to that volume until 1925, when 76 plants were operating in the United States. But by 1929 other processes began to supply the market for the chemical products of hardwood distillation, and by 1940 competition had eliminated so many relatively inefficient units that the industry was down to two-thirds of its former size--35 plants were operating in 1937. Activity increased again during the late war. Most units equipped to recover volatile products then operated at capacity, and the old "pit-burning" method of producing charcoal was revived.

Before 1925-30 chemical products of hardwood distillation carried a fair part of the total costs. Since then competing sources of the chemicals have thrown the main burden on charcoal. Currently about 90 percent of all charcoal is from hardwood distillation. By contrast, however, we get less than a quarter of our commercial acetic acid, and only 10 to 15 percent of our total methanol, from this source. Charcoal is in demand for advanced metallurgy and chemical manufacture. As the viscose rayon industry grows, its requirements

for carbon bisulfide, usually made from charcoal, will increase. Similarly, the expanding light metals industry shows signs of creating local demands for rather large quantities of charcoal, especially, where cheap power and abundant forests are near each other.

Ability to market charcoal, then, will probably determine the course of the hardwood distillation industry. At present the outlook is for a consumption of 600,000 cords annually, about the prewar rate.

Destructive distillation of softwoods

Production of softwood charcoal never amounted to more than about 5 or 6 percent of the prewar production of hardwood charcoal. During the war, local needs stimulated the manufacture of softwood charcoal in the Pacific Northwest, but the industry there may have difficulty in maintaining itself in the postwar period.

Destructive distillation of softwoods is confined mostly to the South. Southern pines are resinous, especially the heartwood of the upper stems and of the stumps left from the virgin crop, which make up most of the pine wood distilled. Wood turpentine, oils, and tar, the volatile byproducts, enter a varied market and help keep the charcoal price down. The distillate of both the southern pines and the northwestern conifers contains methanol and acetic acid, but in amounts too small for economical recovery.

The chemistry of destructive distillation of wood is extremely complex and has been the subject of a great deal of research. Suffice it to say that in both hardwood and softwood distillation the acetic acid appears to be derived mostly from the carbohydrate portion of the wood and the methanol from the lignin. The water and noncondensable gases evolved vary broadly by species, but generally less than half of the dry weight of the wood is recovered as charcoal and valuable distillate.

The important point, however, is that all the carbohydrate portion of the wood--the cellulosic and hemicellulosic fractions which form 65 to 75 percent of the total wood substance--is broken down and only a small fraction recovered. The lignin is destroyed as such and converted to charcoal. The cellulosic and hemicellulosic fractions of the wood are in themselves of greater potential value than the products of their destructive distillation. This is true whether they are separated by chemical means and used as such or broken into their component sugars by hydrolysis, with lignin as the solid residue. If broken down, destructive distillation of the separated lignin gives nearly the full original yield of methanol from the wood and about half of the total yield of charcoal as well as valuable phenols.

In other words, although lignin comprises only about one-fourth of the weight of the wood, it is responsible for about half of the total yield of charcoal. By breaking the cellulosic and hemicellulosic fractions into their component sugars by hydrolysis, a cord of wood (4,000 pounds) should yield a little over a ton of sugar and about 500 to 600 pounds of charcoal and volatile products. Once developed, this combined operation should take large amounts of low-grade wood.

The steam and solvent process

Originated in the early twentieth century, the steam and solvent process extracts turpentine, pine oil, and rosin from the resinous wood of virgin longleaf and slash pine. It removes without change products already in the resinous wood, whereas destructive distillation decomposes the wood and resin to form new products. The wood, hogged into chips and rolled or shredded, is charged into large vertical digesters and steamed to remove the turpentine and the greater part of the pine oil. The steamed wood is then treated with a solvent, usually a petroleum fraction, which dissolves the remaining pine oil, the rosin, and certain other pitchy substances. This solution is then treated to recover rosin and pine oil.

The steam and solvent industry separates and refines the turpentine, oil fractions, and resin acids very efficiently. Its future, however, depends pretty much on the supply of "fat wood" left from the virgin forest. There is doubt that it can operate at its present scale on the stumps of second-growth pine.

It processes slightly over a million tons of fat pine annually. The average ton of wood yields 310 to 320 pounds of rosin, 5.5 gallons of turpentine, and $4\frac{1}{2}$ gallons of pine oil. The exhausted wood has mostly served as fuel for the industry, although an attempt has been made to market a fiberboard product manufactured from the spent chips. Experiments have determined that these chips yield less sugar by hydrolysis than fresh, dry, bark-free wood does, but give an amount equal to that of sawmill wood waste with 25 percent bark. Thus far it has seemed more profitable to use them for fuel than for sugar.

Wood Hydrolysis Industry

"Wood hydrolysis" is the chemical division of wood into simpler units by treatment with acids, alkalies, or a superheated steam. The basic product of the hydrolysis industry is sugar, a raw material from which a series of chemicals can be produced by fermentation. Byproducts are furfural, methanol, and, if recovery is profitable, acetic acid.

As previously remarked, wood is about three-fourths carbohydrate and one-fourth lignin. The carbohydrate fraction consists of different substances, all of which are molecules built up of simple sugars and their derivatives. How these sugars are united chemically determines the nature of the resulting body. Thus pure cellulose, by far the most important and abundant of wood carbohydrates, is composed entirely of molecules of glucose. Several other types of celluloses and a number of complex bodies called hemicelluloses contain sugars with only 5 carbon atoms in distinction from glucose, which contains 6.

Heating wood with acids splits the chemical bonds uniting its components. According to the intensity of the treatment, this process produces lignin, various complex carbohydrate bodies, and mixtures of simple sugars with 6 and 5 carbon atoms. The lignin, which binds the fibers together, remains as an insoluble residue. Theoretically, complete hydrolysis should produce 1,500 pounds of sugar and 500 pounds of lignin per ton of dry wood. It never does, simply because some sugar is destroyed in the process of its formation. However, a process of wood hydrolysis developed by the Forest Products Laboratory during the war yields 1,100 to 1,200 pounds of fermentable and nonfermentable sugar per ton of dry wood. This method is based upon Scholler's process, used in Germany before and during the war.

Wood hydrolysis can be of several intensities, ranging from the drastic process mentioned above to the mere treatment of wood with superheated steam, which liberates a small amount of lignin and a little sugar. Partially hydrolyzed wood is already used for building or insulating boards, but for the most part the plastics industry thus based is in the exploratory stage. An intermediate hydrolysis gives a "ligno-cellulose" molding powder which is principally a complex mixture of lignin and altered carbohydrates. Properly compounded, it is a hard, dense, black molded product of undoubted value. A sugar solution is produced at the same time as the molding powder.

The sugars developed during hydrolysis can be used as raw material for the fermentation industry. The 6-carbon-atom sugars can be fermented to alcohol by appropriate yeasts. Still other yeasts and processes produce from the 5-carbon-atom sugars the protein food described on page 25. The manufacture of this protein would seem to be a good commercial venture for certain areas of this country.

Wood sugar can be converted to other useful products. For example, preliminary calculations indicate the possibility of treating concentrated sugar solutions with sulfuric acid and recovering furfural, a chemical widely used in the petroleum, naval stores, and plastics industries.

The Government-owned plant at Springfield, Oreg., is the only one in this country based on complete wood hydrolysis. It was constructed during and after the war to produce ethyl alcohol by yeast fermentation of wood sugar obtained by hydrolysis. Using the process

developed by the Forest Products Laboratory, it will consume about 325 tons of sawmill waste per day (5 to 7 million cubic feet per year) to produce about 15,000 gallons of pure alcohol, and will recover as byproducts significant amounts of furfural and methanol. If this plant demonstrates that alcohol can be made from wood at competitive prices, the outlet for mill waste may be enlarged.

One of the principal deterrents to increased use of sawmill waste is the cost of getting it to the point of further manufacture. For profitable operation the chips, sawdust, and shavings should not cost over $1.50 to $2.00 per ton (dry weight) at the alcohol plant with alcohol production costs at 25 cents a gallon. This means that at 5 cents per ton-mile, the maximum truck haul cannot be much over 30 miles.

Fermentation produces alcohol and carbon dioxide in approximately equal weights. Recovered and compressed, this carbon dioxide gas becomes the dry ice of commerce. In Germany this carbon dioxide occasionally is a source of methanol, but this use probably is not significant in the United States. Using it for refrigeration in this country might well be practical, however, especially where large-scale forest industries are near valleys which ship fruits and vegetables to distant markets.

In total hydrolysis as it will be carried out in the Oregon alcohol plant, the residue is mostly lignin with a varying percentage of partially decomposed carbohydrate material. It is a brown substance, more or less in the shape of the hogged wood originally charged into the digesters. Chemically, it is rather inert, for it has been subjected to prolonged action of hot sulfuric acid. It is not a very promising material for plastics manufacture but may make a plastics filler or a phenolic resin extender for plywood. It is being tested as a soil improver, for which it has been widely used in Germany.

By the action of hydrogen gas under high pressure, crude lignin can be converted to a wide variety of simple chemicals, some of commercial importance, some new and of unknown usefulness. Among these chemicals are phenols, components of the most important resin used in manufacturing plywood. Another is methanol, from which is made formaldehyde, the other component of this resin. All these things are still in the development stage--their economic soundness remains to be demonstrated. For the immediate future the lignin will probably be burned to generate steam, but chemists hope to find ways of converting it profitably into higher-priced goods.

Tannin Industry

Although its chemistry is fundamentally complex, leather is manufactured fairly simply by soaking hides in a solution containing tannin. The term tannin applies to a whole family of chemical compounds which, in nature, occur in highest concentrations in certain woods, barks, leaves, and fruits. Only a few tannins produce useful leather, the properties of which vary considerably with the tannins used in its preparation.

We use about 300 million pounds of dry tannin a year, of which two-thirds is imported. About 85 percent of the imported tannin is quebracho from Argentina and Paraguay, and 90 percent of the domestic tannin is from dead chestnut wood.

Present domestic sources

Eastern hemlock bark.--Our colonial tanneries used the bark of the eastern hemlock, black oak, and chestnut oak to make the good "oak-hemlock leather" of our forefathers. Later the industry expanded into the Ohio Valley, using white, black, and chestnut oaks, and into the Lake States for hemlock bark. The Ohio Valley phase began to fade early in this century. Production of hemlock bark in the Lake States reached its peak in 1928 of 77,600 cords. From 1902 to 1929, 28 tanneries were operating in Wisconsin and Michigan. Today there are practically no bark tanneries in Wisconsin, and only 4 are left in Michigan.

The heyday of hemlock tannin in the Lake Region coincided with a period of heavy production of hemlock lumber. Hemlock lumbering is less extensive than in earlier years, but produces several times as much hemlock bark as is being marketed. It is estimated that in 1944 the hemlock lumber manufactured and the hemlock pulpwood delivered to pulp mills in the Lake and New England Regions could have supplied close to 30,000 cords of bark, instead of the 8,800 that were produced. This bark provided less than 4 million pounds, or about 1.5 percent of our total tannin requirement. The explanation is simple: In 1944 tannin from hemlock bark cost 20.8 cents per pound, while quebracho extract from the Argentine cost only 13.6 cents per pound of pure tannin.

Chestnut wood.--The only significant current production of tannin materials in the United States comes from the wood of dead chestnut, killed in the epidemic chestnut blight, chiefly between 1910 and 1940. Manufacturing tannin extract from the dead trees has been profitable and important to our continued ability to make good heavy leather. In 1942, 16 plants were manufacturing chestnut extract, 5 each in Virginia, North Carolina, and Tennessee, and 1 in Alabama. These plants produced 362.4 million pounds of 25-percent extract in 1941. Their total operating capacity was estimated at

406.5 million pounds of 25-percent extract, or about 100 million pounds of tannin.

Some new extraction capacity could have been added during the war, but it is estimated that there is only enough wood to supply existing plants until 1960. The wood supply is becoming less accessible, and the tannin content has decreased steadily since the trees died. In 1932, 160 cubic feet of wood yielded an average of 934 pounds of 25-percent extract; in 1940, 800 pounds.

Tanbark oak.--In California a small business in tannin manufacture and tanbark sales is based on the bark of the tanbark oak which grows in mixture with the coast redwoods. Unfortunately, its wood is difficult to season and manufacture into lumber. Hence this species has not been extensively used for the high-grade hardwood it really is, but has been exploited very wastefully for a comparatively small amount of tannin. An estimated 10,000 cords of its bark are used annually against probably 50,000 cords per year during the first World War. This shrinkage is due in large part to the relatively high cost of tannin from this source in comparison with the cost of tannin from quebracho.

The best available data show that about 500,000 cords of tanbark oak bark still stand in California. This is probably an underestimate, but even so there is enough to last nearly 50 years at the present rate of use.

Western hemlock bark.--Perhaps our largest unused source of tannin is the bark of the western hemlock, whose wood is extensively used for lumber and pulp. After considerable experimentation during the war, satisfactory tannin extract was prepared from bark removed before pulping. Good extract can likewise be made by peeling the bark in the woods and aging it much as eastern hemlock bark has been handled. However, the high cost of woods labor in the Pacific Northwest discourages this practice. A successful tannin industry based on western hemlock will probably have to obtain its bark as a byproduct of pulp manufacture. Having been hauled to the mill and there removed by hydraulic barkers, the bark will have, for practical purposes, only its fuel replacement value--low enough to open some industrial possibilities.

Unfortunately, much western hemlock pulpwood is transported in salt water. Salt interferes so seriously with the production of tannin extract that any commercial tannin will probably come entirely from logs hauled by rail or driven in fresh water. This throws estimates open to very large error, but probably 20 million pounds of tannin could be extracted annually from bark at the pulp mills.

Other sources.--Other native trees are potential sources of tannin. The stumps of the coast redwoods contain a satisfactory kind that might be profitably extracted under some conditions. Mangrove bark from the Florida Keys has a high tannin content. The bark of

certain scrub oaks in the Southeast also contains tannin. If the bark can be economically collected and harvested, a successful tannin industry might be based on these species. The 4 to 6 percent of tannin in Douglas-fir bark could be recovered if the very large volume of Douglas-fir saw timber could be peeled and processed economically. The Tennessee Valley Authority is investigating the possibility of extracting tannin from oak and making fiberboard from the chips as is now done with chestnut.

Our future tannin supply

No one can accurately forecast the future tannin market. Factors that must be considered in making predictions on this market include new synthetic tanning agents, new plastics that substitute for leather in some uses, and increasing competition of materials on all fronts. Nevertheless, our own forest byproducts offer enough sources of tannin to meet our probable need. Enterprise must still find the way to exploit these sources.

FUEL USE

It is estimated that, for the period as a whole since the early settlements, fuel has taken over half the total volume cut from our forests for commodity use, and more than twice as much as lumber, its nearest rival. For the past 60 to 70 years, however, the volume of fuel wood used has steadily shrunk. Modern stoves are more efficient than old ones were, and, especially in rural areas, improved living standards and transportation have decreased the use of wood fuel and increased the use of substitutes.

In the past 5 years fuel-wood use has averaged between 65 and 70 million cords. This is about two-fifths of the entire volume of timber removed from the forest in 1944. About 45 percent of this volume is from living trees cut from the forest, 35 percent from industrial waste used for boiler fuel and domestic heating, and 20 percent from dead and cull trees.

The use of wood for fuel will probably shrink still further in the next 2 or 3 decades, perhaps to as low as 50 to 55 million cords per year. This shrinkage should release wood for a higher use. In the Douglas-fir region, for example, cheap electric power during the next few years may free considerable quantities of industrial fuel for manufacture into paper or other chemical products. In many parts of the country shrinking demands for fuel wood will release green-cut timber for use as lumber, pulpwood, and other products of higher value. As the volume of high-quality timber decreases and as education expands the public awareness of timber quality and value, less high-quality wood and more poor-quality trees and species should be burned as fuel. The change will undoubtedly come slowly under the impetus of supply in

relation to demand. It can be accelerated by extension work and research that will develop new markets for the low-quality material.

As has been stated, far more mill waste than logging waste is used for fuel. Fine mill waste is commonly burned under the boilers of industrial plants and sometimes in domestic furnaces. For ease of handling, sawdust and shavings are sometimes compressed into cylinders 12 inches long and 4 inches in diameter. Each cylinder or briquette weighs about 8 pounds and yields about 8,250 British thermal units per pound. In 1944, briquettes sold for $7.50 to $9.00 per ton at points of manufacture, and had about the same fuel value as wood of similar weight and moisture content. It is estimated that bituminous coal selling for $11.25 per ton has the same heat value per dollar as briquettes at $7.50 per ton.

Briquettes appear most likely to succeed commercially in regions like the Pacific Northwest, where suitable wood waste abounds and coal is expensive. Indeed, of the 55 or more briquetting machines operating in the United States all but 2 are in Idaho and northwest Montana, and in the Pacific Coast States. Total annual production of briquettes is about 200,000 tons.

Coarse waste from primary manufacturing plants is sometimes sold as domestic fuel in stove lengths and also as boiler fuel in various lengths. It is also reduced to chip form and used or sold as "hogged fuel" in small, convenient, uniform sizes. Hogged fuel is especially important in the Pacific Coast States. Many stokers for feeding such fuel automatically to domestic and industrial furnaces are used in Oregon and Washington; an estimated 60 percent of total fuel consumption of Seattle and Portland is satisfied by wood. So greatly does the Pacific Northwest depend upon its hogged fuel that during the war the limited supply was under complete allocation. Large sawmills are equipped with "hogs," and the hogged fuel in the Pacific Northwest is transported at reasonable cost as much as 40 or 50 miles by rail and longer distances by barge. To facilitate handling it, railroads provide specially braced boxcars with the roof removed, and with hinged sides for ease in unloading.

LINES OF NEEDED ACTION

It will be evident from consideration of the foregoing suggestions for better utilization that the problem of wood waste reduction is an extremely complex one, and that its solution will have to be worked out gradually and on many fronts. There are, however, certain indicated lines of desirable action that emerge from the mass of detailed observations.

Greater integration of the timber products industries.--By this is meant a variety of logging and manufacturing operations drawing upon the forest resource in a given locality in such a way as to enable more complete and advantageous utilization of the timber that is cut or that ought to be cut.

One-product operating, still typical of the forest industries in this country, tends to be wasteful. Sawlog cutting for manufacture into lumber, for example, usually leaves on the ground material not suitable for lumber, much of which might make good pulpwood, distillation wood, small dimension stock, or some other product less exacting as to its raw material requirements. Fortunately there is a definite trend away from one-product operating, although this tendency still has a long way to go.

Integration may take numerous forms and may be applied at all stages from the purchase of stumpage, through the various woods and plant operations, to the sale of the finished products. Ideally, all high-grade material should go into lumber, veneer, and other high-quality products; and all low-grade into pulp and paper, various other chemical products, building board, fuel, and the like. The unavoidable waste from one stage in processing should be picked up and utilized at a lower stage. Correlation of chemical use of wood with the manufacture of lumber is especially promising. The expanding paper and pulp industry could use more of the wood now wasted in lumber operations, and other chemical industries could use more of the wood substances now carried off in waste pulping liquors.

Integration not only aids in waste reduction but brings about a greater stability of the timber industries and encourages sustained-yield management of timber land.

Extension of sustained-yield forest management.--Cutting on a liquidation basis, particularly prevalent in the case of small operations, is often characteristic of one-product industries. Because mills can operate profitably on such a basis without recovering very much of the total potential volume of wood, they have small incentive for close utilization. Furthermore, there is little interest in keeping down logging damage to residual trees, since the operator does not expect to come back for a second cut on the same land.

On the other hand, incentives for maximum utilization are high where operators plan to stay in business permanently and are dependent upon sustained forest crops. With the adoption of sustained-yield management, the whole attitude towards the land and its resources changes--from one of cutting out and moving on quickly to the next setting to one of settling down on one piece of land and making full and continuous use of its products. Subsidiary or independent industries using raw material or the waste not suited for the primary commodity are encouraged. This kind of a set-up in turn makes for retention of immature trees for later harvesting and other forestry practices that improve the growing stock and increase growth and yield.

The following lines of action are not only in themselves generally useful in reducing waste but are needed to facilitate progress in the two just described.

Research to discover ways of making old products with less waste and to devise new ways of further processing what is now wasted.-- Research has obtained much more information on waste reduction than has been generally applied, but it must keep out in front of the demands made on it. It must devise more efficient logging and manufacturing machinery, improve methods of operating, and discover new ones. It must discover new processes that can be applied to material now wasted or inefficiently used. To this end, research is needed to develop: Cheaper methods of collecting and transporting logging waste; new or improved pulping methods to utilize less desirable species, particularly hardwoods, and the unused portions of trees cut for other products; more efficient methods of reducing wood to sugar and lignin and converting these to industrial products; processes for manufacturing alcohol and food yeast from sulfite waste liquor and for utilizing sulfite lignin; and utilization of small dimension pieces from slabs, short logs, and parts of tree stems.

Technical assistance to woodland owners and wood processors.-- Most woodland owners need technical, on-the-ground advice in all phases of timber management and marketing, including cutting and logging methods that will reduce waste and conserve young growth. Assistance in locating markets for sizes and qualities of wood not in great demand is often needed. Cooperative associations may be of help in solving this problem.

Many processors, especially the small ones, also need technical guidance in the selection of equipment, and in improved mill lay-outs, processes, and machine operation to minimize waste. This kind of help is being provided to a limited extent by public agencies and industry associations, but it is needed on a much larger scale.

Public aid in financing pioneering operations to establish the practicability of given waste-reducing or waste-consuming processes.-- Such assistance would often hasten the commercial application of the findings of research, especially where new investment costs are involved. Credit on favorable terms or, in some special cases, actual subsidy to cover the financial risk of the new enterprise may be needed. In this way government financing would help a private operator put a new process on a commercial basis. If he succeeded, other operators would be encouraged to enter the field, and the general application of the process would be assured.

By application of the kind of measures outlined above, how much can waste be reduced? It is impossible to say. Wood as a chemical raw material is partially interchangeable with petroleum, molasses, and certain agricultural products, and pronounced shifts in the availability or price of these materials can greatly affect the possible competitive use of wood. And good-quality lumber and products such as veneer and poles and piling cannot be made from low-grade or small-size waste material. Economic and technological factors also limit the extent to which the output of lumber and other staple timber products can be increased from a given amount of stumpage.

However, the present great quantity of waste is a continuing challenge. Better utilization would make possible the manufacture of greater quantities and a wider variety of goods without proportionate increase in forest drain. New industries using the waste from logging or processing would expand the utility of wood and enlarge the scope of forest-based industry. Full advantage should be taken of all promising possibilities of better utilization.

While waste reduction can help, it cannot of itself solve the problem of balancing timber growth and drain at the desirable level. It will not do away with the necessity for pushing forward with a comprehensive program of forest rehabilitation and management to increase substantially the rate of growth and ultimately the saw-timber supply.

APPENDIX

The following tables present detailed information on wood waste in logging and primary manufacturing, exclusive of waste of lignin and cellulose in pulping. They were prepared by regional specialists of the Forest Service for their respective regions. In regions where the volume of woods waste per acre logged is considerable, as in the Pacific Northwest, the estimates were based on measurements of waste per unit of log volume on hundreds of sample plots established in recently logged areas. Total woods waste in 1944 was determined by multiplying waste per unit of volume logged by figures on production of lumber, veneer, logs, pulpwood, and other wood products. Manufacturing waste per unit of product was based on waste studies at sawmills and other plants. Total manufacturing waste was derived by multiplying these unit waste figures by the 1944 production.

The proportion of woods and mill waste used as fuel is based on best current information. In certain regions plant operators supplied data on industrial waste used for fuel. Where specific data were not available, as in the case of logging waste, the opinion of informed persons on the proportion of logging waste used for fuel had to be accepted.

The regional waste estimates were reviewed, cross-checked where possible, and correlated with production and drain estimates in the Washington Office of the Forest Service. Although the data presented in the tables are considered reasonably accurate in total, equal reliance cannot be placed on all of the subdivisions.

Table 7.--Logging waste,[1] by product and region - 1944

Region	Parts of cut trees left in woods			Trees destroyed in logging			Total logging waste		
	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total
	Million cubic feet								
Lumber									
North:									
New England	9.6	57.8	67.4	0.4	2.7	3.1	10.0	60.5	70.5
Middle Atlantic	17.5	97.8	115.3	.9	4.7	5.6	18.4	102.5	120.9
Lake	13.9	124.4	138.3	.5	10.4	10.9	14.4	134.8	149.2
Central	18.0	162.1	180.1	.3	6.3	6.6	18.3	168.4	186.7
Plains	1.5	1.1	2.6	.1	..	.1	1.6	1.1	2.7
Total	60.5	443.2	503.7	2.2	24.1	26.3	62.7	467.3	530.0
South:									
South Atlantic	33.8	113.1	146.9	12.4	44.3	56.7	46.2	157.4	203.6
Southeast	34.1	274.2	308.3	3.2	37.7	40.9	37.3	311.9	349.2
West Gulf	20.7	215.1	235.8	.2	40.0	40.2	20.9	255.1	276.0
Total	88.6	602.4	691.0	15.8	122.0	137.8	104.4	724.4	828.8
West:									
Pacific Northwest	..	668.0	668.0	..	44.2	44.2	..	712.2	712.2
California	..	81.5	81.5	..	38.7	38.7	..	120.2	120.2
North Rocky Mountain	..	39.3	39.3	..	15.1	15.1	..	54.4	54.4
South Rocky Mountain	.8	11.6	12.4	..	.5	.5	.8	12.1	12.9
Total	.8	800.4	801.2	..	98.5	98.5	.8	898.9	899.7
United States	149.9	1,846.0	1,995.9	18.0	244.6	262.6	167.9	2,090.6	2,258.5
Fuel wood									
North:									
New England	..	12.7	12.7	..	3.7	3.7	..	16.4	16.4
Middle Atlantic	..	12.6	12.6	..	3.5	3.5	..	16.1	16.1
Lake	..	9.3	9.3	..	..	..	..	9.3	9.3
Central	..	46.2	46.2	..	..	..	..	46.2	46.2
Total	..	80.8	80.8	..	7.2	7.2	..	88.0	88.0
South:									
South Atlantic	..	20.2	20.2	..	14.3	14.3	..	34.5	34.5
Southeast	..	38.9	38.9	..	13.5	13.5	..	52.4	52.4
West Gulf	..	10.7	10.7	..	..	..	..	10.7	10.7
Total	..	69.8	69.8	..	27.8	27.8	..	97.6	97.6
West:									
Pacific Northwest	..	12.0	12.0	..	..	..	..	12.0	12.0
North Rocky Mountain	..	1.5	1.5	..	..	..	..	1.5	1.5
South Rocky Mountain	..	.3	.3	..	..	..	..	.3	.3
Total	..	13.8	13.8	..	..	..	..	13.8	13.8
United States	..	164.4	164.4	..	35.0	35.0	..	199.4	199.4
Pulp and Paper									
North:									
New England	3.4	16.2	19.6	0.7	3.3	4.0	4.1	19.5	23.6
Middle Atlantic	.8	4.4	5.2	.1	.4	.5	.9	4.8	5.7
Lake	..	17.5	17.5	..	1.8	1.8	..	19.3	19.3
Central	..	2.8	2.8	..	.3	.3	..	3.1	3.1
Total	4.2	40.9	45.1	.8	5.8	6.6	5.0	46.7	51.7
South:									
South Atlantic	..	13.6	13.6	..	6.4	6.4	..	20.0	20.0
Southeast	..	18.0	18.0	..	2.7	2.7	..	20.7	20.7
West Gulf	..	10.6	10.6	..	1.5	1.5	..	12.1	12.1
Total	..	42.2	42.2	..	10.6	10.6	..	52.8	52.8
West:									
Pacific Northwest	..	110.8	110.8	..	4.3	4.3	..	115.1	115.1
North Rocky Mountain	..	.7	.7	..	..	..	..	.7	.7
Total	..	111.5	111.5	..	4.3	4.3	..	115.8	115.8
United States	4.2	194.6	198.8	.8	20.7	21.5	5.0	215.3	220.3

1/ Volume is exclusive of bark.

Table 7.--Logging waste,[1] by product and region - 1944--continued

Hewed crossties

Region	Parts of cut trees left in woods: Used for fuel	Parts of cut trees left in woods: Not used at all	Parts of cut trees left in woods: Total	Trees destroyed in logging: Used for fuel	Trees destroyed in logging: Not used at all	Trees destroyed in logging: Total	Total logging waste: Used for fuel	Total logging waste: Not used at all	Total logging waste: Total
	Million cubic feet								
North:									
New England	0.4	0.7	1.1	0.1	0.1	0.2	0.5	0.8	1.3
Middle Atlantic	.2	1.0	1.2	.1	.7	.8	.3	1.7	2.0
Lake	..	.3	.3	..	..	..	..	.3	.3
Central	.2	1.8	2.0	.1	.2	.3	.3	2.0	2.3
Total	.8	3.8	4.6	.3	1.0	1.3	1.1	4.8	5.9
South:									
South Atlantic	1.8	5.6	7.4	.4	1.4	1.8	2.2	7.0	9.2
Southeast	8.3	51.2	59.5	.1	4.5	4.6	8.4	55.7	64.1
West Gulf	3.2	22.1	25.3	..	2.4	2.4	3.2	24.5	27.7
Total	13.3	78.9	92.2	.5	8.3	8.8	13.8	87.2	101.0
West:									
California	..	.5	.5	..	.2	.2	..	.7	.7
United States	14.1	83.2	97.3	.8	9.5	10.3	14.9	92.7	107.6

Cooperage stock

Region	Parts of cut trees left in woods: Used for fuel	Parts of cut trees left in woods: Not used at all	Parts of cut trees left in woods: Total	Trees destroyed in logging: Used for fuel	Trees destroyed in logging: Not used at all	Trees destroyed in logging: Total	Total logging waste: Used for fuel	Total logging waste: Not used at all	Total logging waste: Total
North:									
New England	0.1	0.5	0.6	0.1	0.3	0.4	0.2	0.8	1.0
Middle Atlantic	.2	1.9	2.1	.2	1.0	1.2	.4	2.9	3.3
Lake	..	.2	.2	..	..	..	..	.2	.2
Central	1.3	10.5	11.8	..	.6	.6	1.3	11.1	12.4
Total	1.6	13.1	14.7	.3	1.9	2.2	1.9	15.0	16.9
South:									
South Atlantic	.2	.6	.8	..	.2	.2	.2	.8	1.0
Southeast	1.5	22.1	23.6	..	.6	.6	1.5	22.7	24.2
West Gulf	1.3	27.6	28.9	..	.3	.3	1.3	27.9	29.2
Total	3.0	50.3	53.3	..	1.1	1.1	3.0	51.4	54.4
West:									
Pacific Northwest	..	2.9	2.9	..	.1	.1	..	3.0	3.0
California	..	.8	.8	..	..	..	..	.8	.8
Total	..	3.7	3.7	..	.1	.1	..	3.8	3.8
United States	4.6	67.1	71.7	.3	3.1	3.4	4.9	70.2	75.1

Fence posts

Region	Parts of cut trees left in woods: Used for fuel	Parts of cut trees left in woods: Not used at all	Parts of cut trees left in woods: Total	Trees destroyed in logging: Used for fuel	Trees destroyed in logging: Not used at all	Trees destroyed in logging: Total	Total logging waste: Used for fuel	Total logging waste: Not used at all	Total logging waste: Total
North:									
New England	0.2	0.3	0.5	0.1	0.2	0.3	0.3	0.5	0.8
Middle Atlantic	..	.2	.2	..	.1	.1	..	.3	.3
Lake	..	1.8	1.8	..	..	..	..	1.8	1.8
Central	.2	4.6	4.8	..	..	..	.2	4.6	4.8
Plains	.5	.4	.9	..	..	..	.5	.4	.9
Total	.9	7.3	8.2	.1	.3	.4	1.0	7.6	8.6
South:									
South Atlantic	..	3.8	3.8	..	.9	.9	..	4.7	4.7
Southeast	.2	1.0	1.2	..	.4	.4	.2	1.4	1.6
West Gulf	.2	1.0	1.2	..	..	..	.2	1.0	1.2
Total	.4	5.8	6.2	..	1.3	1.3	.4	7.1	7.5
West:									
Pacific Northwest	..	.9	.9	..	..	..	..	.9	.9
California	..	1.9	1.9	..	..	..	..	1.9	1.9
North Rocky Mountain	..	.3	.3	..	..	..	..	.3	.3
Total	..	3.1	3.1	..	..	..	..	3.1	3.1
United States	1.3	16.2	17.5	.1	1.6	1.7	1.4	17.8	19.2

Table 7.--Logging waste,[1] by product and region - 1944--continued

Veneer

Region	Parts of cut trees left in woods			Trees destroyed in logging			Total logging waste		
	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total
	Million cubic feet								
North:									
New England	1.3	5.5	6.8	0.4	2.3	2.7	1.7	7.8	9.5
Middle Atlantic	.2	2.7	2.9	.1	1.4	1.5	.3	4.1	4.4
Lake	.8	7.7	8.5	.1	.9	1.0	.9	8.6	9.5
Central	.3	2.5	2.8	..	.1	.1	.3	2.6	2.9
Total	2.6	18.4	21.0	.6	4.7	5.3	3.2	23.1	26.3
South:									
South Atlantic	2.6	7.2	9.8	1.0	2.8	3.8	3.6	10.0	13.6
Southeast	1.3	24.4	25.7	.1	7.9	8.0	1.4	32.3	33.7
West Gulf	.6	12.9	13.5	..	4.5	4.5	.6	17.4	18.0
Total	4.5	44.5	49.0	1.1	15.2	16.3	5.6	59.7	65.3
West:									
Pacific Northwest	..	55.4	55.4	..	2.3	2.3	..	57.7	57.7
United States	7.1	118.3	125.4	1.7	22.2	23.9	8.8	140.5	149.3
Round mine timbers									
North:									
Middle Atlantic	0.3	2.1	2.4	0.1	1.3	1.4	0.4	3.4	3.8
Lake	..	3.5	3.5	..	..	..	..	3.5	3.5
Central	..	10.2	10.2	..	..	..	..	10.2	10.2
Total	.3	15.8	16.1	.1	1.3	1.4	.4	17.1	17.5
South:									
South Atlantic	..	1.9	1.9	..	.3	.3	..	2.2	2.2
Southeast	..	.3	.3	..	.1	.1	..	.4	.4
Total	..	2.2	2.2	..	.4	.4	..	2.6	2.6
West:									
North Rocky Mountain	..	.6	.6	..	.2	.2	..	.8	.8
South Rocky Mountain	..	.8	.8	..	..	..	..	.8	.8
Total	..	1.4	1.4	..	.2	.2	..	1.6	1.6
United States	.3	19.4	19.7	.1	1.9	2.0	.4	21.3	21.7
Shingles									
North:									
Lake	..	0.1	0.1	..	..	..	..	0.1	0.1
South:									
South Atlantic	..	.1	.1	..	..	..	..	.1	.1
West:									
Pacific Northwest	..	19.0	19.0	..	0.7	0.7	..	19.7	19.7
North Rocky Mountain	..	.1	.1	..	..	..	..	.1	.1
Total	..	19.1	19.1	..	.7	.7	..	19.8	19.8
United States	..	19.3	19.3	..	.7	.7	..	20.0	20.0

Table 7.--Logging waste,[1] by product and region - 1944--continued

Other products

Region	Parts of cut trees left in woods: Used for fuel	Parts of cut trees left in woods: Not used at all	Parts of cut trees left in woods: Total	Trees destroyed in logging: Used for fuel	Trees destroyed in logging: Not used at all	Trees destroyed in logging: Total	Total logging waste: Used for fuel	Total logging waste: Not used at all	Total logging waste: Total
	Million cubic feet								
North:									
New England	0.5	6.1	6.6	..	..	..	0.5	6.1	6.6
Middle Atlantic	.3	3.1	3.4	..	0.7	0.7	.3	3.8	4.1
Lake	.1	6.8	6.9	..	.1	.1	.1	6.9	7.0
Central	..	24.0	24.0	..	..	..	..	24.0	24.0
Total	.9	40.0	40.9	..	.8	.8	.9	40.8	41.7
South:									
South Atlantic	1.4	5.2	6.6	0.3	1.5	1.8	1.7	6.7	8.4
Southeast	.9	8.8	9.7	.1	1.1	1.2	1.0	9.9	10.9
West Gulf	.8	8.7	9.5	..	1.6	1.6	.8	10.3	11.1
Total	3.1	22.7	25.8	.4	4.2	4.6	3.5	26.9	30.4
West:									
Pacific Northwest	..	5.7	5.7	..	.3	.3	..	6.0	6.0
California	..	2.6	2.6	..	.7	.7	..	3.3	3.3
North Rocky Mountain	..	1.5	1.5	..	.1	.1	..	1.6	1.6
South Rocky Mountain	..	.4	.4	..	..	..	..	.4	.4
Total	..	10.2	10.2	..	1.1	1.1	..	11.3	11.3
United States	4.0	72.9	76.9	.4	6.1	6.5	4.4	79.0	83.4

Table 8.--Manufacturing waste, by product and region - 1944[1]

Lumber

Region	Slabs and coarse material[2]: Used for fuel	Slabs and coarse material[2]: Not used at all	Slabs and coarse material[2]: Total	Sawdust and fine material: Used for fuel	Sawdust and fine material: Not used at all	Sawdust and fine material: Total	Total manufacturing waste: Used for fuel	Total manufacturing waste: Not used at all	Total manufacturing waste: Total
	Million cubic feet								
North:									
New England	24.3	5.8	30.1	12.6	15.6	28.2	36.9	21.4	58.3
Middle Atlantic	29.9	12.2	42.1	12.6	27.7	40.3	42.5	39.9	82.4
Lake	19.6	10.6	30.2	1.9	16.2	18.1	21.5	26.8	48.3
Central	25.4	17.0	42.4	2.7	24.1	26.8	28.1	41.1	69.2
Plains	1.7	..	1.7	1.0	.3	1.3	2.7	.3	3.0
Total	100.9	45.6	146.5	30.8	83.9	114.7	131.7	129.5	261.2
South:									
South Atlantic	148.1	34.1	182.2	51.5	100.5	152.0	199.6	134.6	334.2
Southeast	158.3	138.4	296.7	97.8	110.9	208.7	256.1	249.3	505.4
West Gulf	102.4	53.6	156.0	71.3	34.4	105.7	173.7	88.0	261.7
Total	408.8	226.1	634.9	220.6	245.8	466.4	629.4	471.9	1,101.3
West:									
Pacific Northwest	236.3	66.7	303.0	300.9	59.2	360.1	537.2	125.9	663.1
California	27.6	42.3	69.9	69.9	17.5	87.4	97.5	59.8	157.3
North Rocky Mountain	16.2	25.7	41.9	20.5	32.1	52.6	36.7	57.8	94.5
South Rocky Mountain	9.9	5.4	15.3	6.6	9.5	16.1	16.5	14.9	31.4
Total	290.0	140.1	430.1	397.9	118.3	516.2	687.9	258.4	946.3
United States	799.7	411.8	1,211.5	649.3	448.0	1,097.3	1,449.0	859.8	2,308.8

Table 8.--Manufacturing waste, by product and region - 1944[1]--continued

Pulp and paper[3]

Region	Slabs and coarse material[2]: Used for fuel	Slabs and coarse material: Not used at all	Slabs and coarse material: Total	Sawdust and fine material: Used for fuel	Sawdust and fine material: Not used at all	Sawdust and fine material: Total	Total manufacturing waste: Used for fuel	Total manufacturing waste: Not used at all	Total manufacturing waste: Total
	Million cubic feet								
North:									
New England	8.0	..	8.0	6.4	..	6.4	14.4	..	14.4
Middle Atlantic	2.0	..	2.0	2.2	..	2.2	4.2	..	4.2
Lake	11.0	..	11.0	8.0	..	8.0	19.0	..	19.0
Central	..	..	..	1.4	..	1.4	1.4	..	1.4
Total	21.0	..	21.0	18.0	..	18.0	39.0	..	39.0
South:									
South Atlantic	5.0	..	5.0	8.0	..	8.0	13.0	..	13.0
Southeast	9.0	..	9.0	12.0	..	12.0	21.0	..	21.0
West Gulf	6.0	..	6.0	7.0	..	7.0	13.0	..	13.0
Total	20.0	..	20.0	27.0	..	27.0	47.0	..	47.0
West:									
Pacific Northwest	14.0	..	14.0	14.0	..	14.0	28.0	..	28.0
United States	55.0	..	55.0	59.0	..	59.0	114.0	..	114.0

Hewed crossties

Region	Slabs and coarse material: Used for fuel	Slabs and coarse material: Not used at all	Slabs and coarse material: Total	Sawdust and fine material: Used for fuel	Sawdust and fine material: Not used at all	Sawdust and fine material: Total	Total manufacturing waste: Used for fuel	Total manufacturing waste: Not used at all	Total manufacturing waste: Total
North:									
New England	..	3.9	3.9	..	..	..	..	3.9	3.9
Middle Atlantic	..	4.4	4.4	..	..	..	..	4.4	4.4
Lake	..	.7	.7	..	..	..	..	.7	.7
Central	..	9.5	9.5	..	..	..	..	9.5	9.5
Total	..	18.5	18.5	..	..	..	..	18.5	18.5
South:									
South Atlantic	..	9.1	9.1	..	..	..	..	9.1	9.1
Southeast	..	57.6	57.6	..	..	..	..	57.6	57.6
West Gulf	..	60.6	60.6	..	..	..	..	60.6	60.6
Total	..	127.3	127.3	..	..	..	..	127.3	127.3
West:									
California	..	.8	.8	..	..	..	..	.8	.8
United States	..	146.6	146.6	..	..	..	..	146.6	146.6

Cooperage stock

Region	Slabs and coarse material: Used for fuel	Slabs and coarse material: Not used at all	Slabs and coarse material: Total	Sawdust and fine material: Used for fuel	Sawdust and fine material: Not used at all	Sawdust and fine material: Total	Total manufacturing waste: Used for fuel	Total manufacturing waste: Not used at all	Total manufacturing waste: Total
North:									
New England	0.5	..	0.5	0.3	..	0.3	0.8	..	0.8
Middle Atlantic	.5	..	.5	.3	0.2	.5	.8	0.2	1.0
Lake	.1	..	.1	..	..	..	.1	..	.1
Central	4.2	0.5	4.7	.1	2.5	2.6	4.3	3.0	7.3
Total	5.3	.5	5.8	.7	2.7	3.4	6.0	3.2	9.2
South:									
South Atlantic	1.6	..	1.6	..	4.2	4.2	1.6	4.2	5.8
Southeast	9.2	1.6	10.8	4.9	2.6	7.5	14.1	4.2	18.3
West Gulf	7.5	1.4	8.9	4.2	1.7	5.9	11.7	3.1	14.8
Total	18.3	3.0	21.3	9.1	8.5	17.6	27.4	11.5	38.9
West:									
Pacific Northwest	1.0	..	1.0	1.1	..	1.1	2.1	..	2.1
California	..	..	..	.3	.3	.6	.3	.3	.6
Total	1.0	..	1.0	1.4	.3	1.7	2.4	.3	2.7
United States	24.6	3.5	28.1	11.2	11.5	22.7	35.8	15.0	50.8

Table 8.--Manufacturing waste, by product and region - 1944[1]--continued

Fence posts

Region	Slabs and coarse material[2]			Sawdust and fine material			Total manufacturing waste		
	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total
	Million cubic feet								
South:									
South Atlantic	..	..	..	..	1.5	1.5	..	1.5	1.5
Southeast	..	..	..	..	.7	.7	..	.7	.7
Total	..	..	..	..	2.2	2.2	..	2.2	2.2
West:									
North Rocky Mountain	..	0.1	0.1	..	.1	.1	..	.2	.2
United States	..	.1	.1	..	2.3	2.3	..	2.4	2.4

Veneer

Region	Slabs and coarse material[2]			Sawdust and fine material			Total manufacturing waste		
	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total
North:									
New England	1.1	..	1.1	1.8	..	1.8	2.9	..	2.9
Middle Atlantic	1.0	..	1.0	1.1	..	1.1	2.1	..	2.1
Lake	4.6	0.2	4.8	..	..	..	4.6	0.2	4.8
Central	1.6	.1	1.7	..	..	..	1.6	.1	1.7
Total	8.3	.3	8.6	2.9	..	2.9	11.2	.3	11.5
South:									
South Atlantic	5.3	..	5.3	8.3	0.4	8.7	13.6	.4	14.0
Southeast	6.8	..	6.8	21.2	.1	21.3	28.0	.1	28.1
West Gulf	2.9	..	2.9	9.5	..	9.5	12.4	..	12.4
Total	15.0	..	15.0	39.0	.5	39.5	54.0	.5	54.5
West:									
Pacific Northwest	28.1	..	28.1	14.0	..	14.0	42.1	..	42.1
California	.2	..	.2	1.8	..	1.8	2.0	..	2.0
Total	28.3	..	28.3	15.8	..	15.8	44.1	..	44.1
United States	51.6	.3	51.9	57.7	.5	58.2	109.3	.8	110.1

Round mine timbers

Region	Slabs and coarse material[2]			Sawdust and fine material			Total manufacturing waste		
	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total
North:									
Middle Atlantic	3.4	0.4	3.8	..	..	..	3.4	0.4	3.8
United States	3.4	.4	3.8	..	..	..	3.4	.4	3.8

Shingles

Region	Slabs and coarse material[2]			Sawdust and fine material			Total manufacturing waste		
	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total
North:									
New England	0.1	..	0.1	0.1	0.1	0.2	0.2	0.1	0.3
Lake	.1	..	.1	..	.2	.2	.1	.2	.3
Total	.2	..	.2	.1	.3	.4	.3	.3	.6
South:									
South Atlantic	..	..	..	..	.2	.2	..	.2	.2
West:									
Pacific Northwest	1.8	0.6	2.4	10.7	10.7	21.4	12.5	11.3	23.8
California	.1	.1	.2	.1	.2	.3	.2	.3	.5
North Rocky Mountain	..	.1	.1	..	..	..	..	.1	.1
Total	1.9	.8	2.7	10.8	10.9	21.7	12.7	11.7	24.4
United States	2.1	.8	2.9	10.9	11.4	22.3	13.0	12.2	25.2

Table 8.--Manufacturing waste, by product and region - 1944[1]--continued

Other products

Region	Slabs and coarse material[2]			Sawdust and fine material			Total manufacturing waste		
	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total	Used for fuel	Not used at all	Total
	Million cubic feet								
North:									
New England	12.4	..	12.4	9.6	0.4	10.0	22.0	0.4	22.4
Middle Atlantic	7.3	0.2	7.5	7.2	3.5	10.7	14.5	3.7	18.2
Lake	3.8	1.0	4.8	.5	2.0	2.5	4.3	3.0	7.3
Central	14.2	3.5	17.7	1.7	7.0	8.7	15.9	10.5	26.4
Total	37.7	4.7	42.4	19.0	12.9	31.9	56.7	17.6	74.3
South:									
South Atlantic	4.1	..	4.1	10.4	1.0	11.4	14.5	1.0	15.5
Southeast	2.1	.9	3.0	2.5	1.8	4.3	4.6	2.7	7.3
West Gulf	2.1	1.1	3.2	3.2	1.6	4.8	5.3	2.7	8.0
Total	8.3	2.0	10.3	16.1	4.4	20.5	24.4	6.4	30.8
West:									
North Rocky Mountain	1.6	.6	2.2	.3	.3	.6	1.9	.9	2.8
South Rocky Mountain	..	.4	.4	..	.3	.3	..	.7	.7
Total	1.6	1.0	2.6	.3	.6	.9	1.9	1.6	3.5
United States	47.6	7.7	55.3	35.4	17.9	53.3	83.0	25.6	108.6

1/ Volume is exclusive of bark.

2/ Includes ax (chip) waste in any hewed product.

3/ Includes losses only in the form of wood; excludes losses in chemical fractions such as lignin.

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